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ESCAPE SYSTEM TRAJECTORY SENSITIVITY ANALYSIS.

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Several modeling changes were performed on existing Trajectory Simulation Computer Programs to simulate the operation of various escape systems. A study was conducted to identify significant input parameters and the models' response to variations in the parameter values. A performance envelope plot was derived for each escape system by considering large deviations in the values of these parameters from their base values.

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FOREWORD

This final report describes the work accomplished by Computer Sciences Corporation for the Aircraft and Crew Systems Technology Directorate of the Naval Air Development Center, Warminster, Pennsylvania, in accordance with the requirements defined by Task Order 0047, "Escape System Trajectory Sensitivity Analysis", issued under Contract N62269-75-C-0001. This work was sponsored by the Naval Air Systems Command under AirTask A5365360/001D/8W0625-0000 and was monitored by Mr. Louis D'Aulerio and Mr. Alan Cantor of NADC.

SECTION I

SUMMARY

At the request of the Naval Air Development Center Crew Systems Department, the Computer Sciences Corporation initiated a study to identify significant input parameters to two existing mathematical seat ejection models (DEDALUS, a two dimensional model and ICARUS, a three dimensional model). CSC was also requested to ascertain the models' response to variations in the input parameter values.

1.1 INPUT DATA SELECTION

Two physically different seat ejection configurations (rocket position, rocket angle, seat/man center of gravity, etc.) were used in the study. The following eight input parameters were selected to be varied: the seat/man center of gravity, catapult thrust, rocket thrust, rocket angle, rocket ignition, rocket position, seat/man moments of inertia and the aerodynamic coefficients. The above eight parameters are common to both models.

1.2 METHODOLOGY USED IN STUDY

The effects on the seat/man ejection trajectory, by varying the parameters by a plus or minus twenty percent for both configurations, were analyzed under zero and six hundred knots initial velocity conditions. The varied parameter ejection trajectories and their corresponding base case trajectory were then plotted. The mean values and standard deviations of the differences between the varied parameter's trajectories and their corresponding base case trajectory, over specified phases of the trajectory were computed. The specified phases were catapult ignition to catapult separation, rocket ignition to rocket burnout, rocket burnout to drogue chute projection, and drogue projection to one second. The parameters were then ranked using their respective means and standard deviations as the ranking criterion. The statistical significance, of each ranking of the parameters obtained, was ascertained by computing a Coefficient of Concordance, the associated F-test value at the 95% confidence level and Spearman's Rank Correlation Coefficient. These coefficients were computed as a function of the above rankings.

1.3 ANALYSIS OF RESULTS OBTAINED

Analysis of the results obtained from the study indicates that all eight variables are significant. Each of the eight parameters, when varied by a plus or minus twenty percent, is ranked either first, second or third at least once with respect to the amount it caused a trajectory component to differ from the component's corresponding base case set of values.

The following factors were found to influence the individual and combined trajectory component rankings obtained during the study:

1) the trajectory components responded differently from one another to the variations in the input parameter values.

2) the rankings of the parameters are effected by initial velocity differences (zero knots versus 600 knots).

3) the rankings of the parameters are effected by the differences existing between the two sets of base case values.

A separate analysis, not included in the above main analysis, identified the weight of the seat/man combination as being a significant input parameter.

A limited analysis of the effects on the ejection trajectory when two or three of the input parameters are varied simultaneously by a plus or minus twenty percent indicates certain combinations of the parameters tend to minimize the differences between the base case trajectory and the varied parameter's trajectory, while other combinations tended to maximize the differences.

An additional case was constructed whereby the eight input parameters were varied by a small amount simultaneously. The difference between the trajectory generated with the eight parameters set at these values and their corresponding base case trajectory values was almost as great as the maximum difference observed when the eight parameters were varied one at a time by a plus or minus twenty percent.

1.4 RECOMMENDATION

A recommendation as to how the model(s) could be modified to arrive at an envelope of trajectories surrounding the base case trajectory is given. This envelope of trajectories would be generated stochastically taking into account the degree of uncertainty associated with specific or all of the input parameters and the effects of varying the parameters simultaneously.

SECTION 2

INTRODUCTION

The following report documents the work completed by Computer Sciences Corporation under Task Order Number 47, Contract N62269-75-C-0001 for the Naval Air Development Center, Crew Systems Engineering Division, Warminster, Pennsylvania. The report is in two parts.

2.1 DESCRIPTION OF THE FIRST PART OF THE REPORT

The first part of the report, Sections 3 to 6, documents the methodology used and the results obtained while using this methodology to identify the significant input parameters to two existing seat ejection mathematical simulation models, programmed in Fortran and executed on the CDC 6600 Computer.

2.1.1 <u>Description of the Two Seat Ejection Simulation Models</u>. The two models referenced here are DEDALUS, a two dimensional model, and ICARUS, a three dimensional model. DEDALUS describes the seat/man ejection trajectory in the plane of the horizontal x-axis and vertical z-axis. The above seat/man spatial coordinators (x, z) are computed by the model at each integration time step. The angular rate of rotation (pitching rate) in this plane is also computed by the model.

The three dimensional model (ICARUS, a six degrees of freedom model) completely describes the ejection trajectory. The three linear spatial coordinates (x, y and z) and the three angular rates of motion (p, q and r corresponding to roll, pitch and yaw respectively) of the seat/man ejection trajectory are computed by the model.

2.1.2 <u>Description of the Base Case and Varied Parameter Trajectories</u>. As an aid in the identification of the significant input parameters to the ejection seat models, it was decided to set the input parameters to their base case values and to generate a seat/man ejection trajectory (via the models) using these values as input to the model(s). The base case value being defined here to mean the best estimate of the input parameter's true value for a given physical seat-ejection system. The input parameters were varied one at a time and an ejection trajectory was generated, via the model, for each variable varied.

From past experience in the use of the models, it was noted that when an individual parameter was varied from a given initial value, the variable had to be varied anywhere from fifteen to twenty five percent before a

consistent noticeable change in the trajectory (relative to the initial trajectory) was observed. For the purposes of this study, it was decided to vary the input parameters one at a time - first by a plus twenty percent then by a minus twenty percent. An ejection trajectory was then generated with one of the input parameters set to a plus twenty percent increase in value over its base case value while the other input parameters were held constant at their respective base case values. Similarly, an ejection trajectory was generated, with the above parameter set to a minus twenty percent decrease in value from its base case value. These trajectories were then used to identify the significant input parameters and to measure the models' response (relative to the base case trajectory) to the variation in the parameter's base case value.

2.1.3 Summary Report Implementation. In order to reduce the time and cost of generating an individual ejection trajectory via the models on the computer, a summary report displaying the above linear and angular components of the trajectory was designed and implemented in both models. The models were then further modified to generate an output file of records containing the time followed by the values of the spatial coordinates and the angular rate(s) of the trajectory corresponding to the time value indicated. Thus, a separate file containing the profile of time and the trajectory component values was retained for each trajectory generated by the model(s).

2.1.4 Description of the Plotting and Statistical Programs used in the Study. The above files were later used as input to two other programs. One program, based upon the information contained in the files caused the trajectory data to be plotted. The other program, which was especially written for this study, performed a statistical comparison between any two of the above generated trajectory files. This program was used to perform a statistical comparison between a given base case trajectory component profile and a corresponding varied parameter trajectory component profile. A detailed explanation of how the above generated trajectories were used to identify the significant input parameters and to measure quantitatively the models' response to an input parameter being varied is contained in the succeeding sections of this report.

2.1.5 Explanation of the Numerical Integrating Algorithm Modification. Also, to further reduce the time required and the associated cost of generating an ejection trajectory using the three dimensional model (ICARUS), the fourth order Runge-Kutta integrating algorithm used in ICARUS was replaced with a Runge-Kutta/Simpson's rule integrating scheme. The Runge-Kutta algorithm was used to obtain starting solutions for the Simpson's rule algorithm and to ascertain the precise time a position or time event occurred.

The Simpson's rule algorithm was used for all constant step size integrations once the required number of starting solutions were obtained. The replacement of the Runge-Kutta algorithm with the Runge-Kutta/Simpson's Rule scheme resulted in reducing the cost of generating a seat ejection trajectory on the computer by a factor of one-half.

A comparison of the trajectory components generated using the Runge-Kutta throughout the trajectory, as compared to the Runge-Kutta/Simpson rule scheme, indicated that for the low velocity cases - the trajectory components generated by both integrating schemes were within two percent of each other after four seconds of the trajectory simulation. However, a comparison of the trajectory components generated by both schemes at the 600 knot initial velocity indicated that, after 1.5 seconds of the trajectory, the components disagreed by as much as five percent. In addition, both integrating schemes exhibited instability when a integration step size of .005 or less was used after drogue chute projection.

Based upon the above integrating cost analysis and step size requirements, it was decided to use the Runge-Kutta/Simpson rule algorithm, keeping the integrating step size constant at .001 throughout the trajectory simulation, and to perform the input parameter study using the values obtained for one second of the simulation trajectory; thus, minimizing the errors due to the numerical integration.

2.1.6 Preliminary Case Studies. Finally, a series of preliminary case studies were executed on the computer via the two models. Because of the rather low cost per an ejection trajectory generation associated with the two dimensional model, DEDALUS was used mainly during this initial stage of the study.

The purpose of this preliminary investigation was to:

1) insure that a ± 20% variation level was sufficient to detect differences between the base case and the varied parameter trajectory components.

2) insure that both models responded similarly to the variables varied taking into account one was a two dimensional and the other a three dimensional model.

3) perform a preliminary screening as to which of the input parameters were to be used in the main body of the study.

2.1.7 <u>Results of the Preliminary Case Studies</u>. As a result of the above preliminary study, the following was verified or accomplished:

1) a ± 20% variation level was sufficient to detect differences between the two trajectories.

2) both models do respond in the same way to the variables varied taking into account one is a 2-dimensional model while the other is a 3-dimensional model.

3) a preliminary screening of the input parameters yielded the following list of eight parameters to be used in the main portion of the study:

   a) the seat/man center of gravity (S/M C.G.)

   b) the catapult time/thrust table (Cat Thr)

   c) the rocket time/thrust table (Roc Thr)

   d) the distance in the vertical direction that the rocket must travel (relative to its initial position) before it is ignited (Roc On)

   e) the seat/man moments of inertia (S/M M.I.)

   f) the rocket location with respect to the catapult (Roc Pos)

   g) the seat/man aerodynamic coefficient table (Aero)

Section 3 of this report gives a detailed description of the above eight parameters.

Section 4 explains the methodology used to quantify and to generate the rankings of the eight input parameters with respect to the amount they disturbed the six components of the trajectory (relative to their respective base case values) when varied.

Section 5 explains the results obtained from the study while using the above methodology.

Section 6 recommends an approach to be taken in determining the model(s) response to the simultaneous varying of certain or all of the input parameters from their base case values.

2.2 DESCRIPTION OF THE SECOND PART OF THE REPORT

The second part of the report, Section 7, documents the work completed to date by Computer Sciences Corporation in modifying and extending the capabilities of the above two seat ejection models.

SECTION 3

DEFINITION OF THE EIGHT INPUT PARAMETERS SELECTED TO BE VARIED IN THE STUDY

3.1 SEAT/MAN CENTER OF GRAVITY (S/M C.G.).

Center of gravity of the seat/man combination. The x, y and z coordinates of this parameter being specified in the Catapult Coordinate System (CCS) in units of feet.

3.2 CATAPULT TIME/THRUST TABLE (CAT THR).

Table of values displaying the elapsed time relative to catapult ignition and the corresponding force that the catapult exerts on the seat/man combination at that specific time in units of lbs.

3.3 ROCKET TIME/THRUST TABLE (ROC THR).

Table of values displaying the elapsed time relative to rocket ignition and the corresponding force that the rocket exerts on the seat/man combination at that specific time in units of lbs.

3.4 ROCKET THRUST ANGLES (ROC ANG).

The angles that the rocket thrust line makes with the catapult coordinate axis in units of degrees.

3.5 ROCKET IGNITION LENGTH (ROC ON).

The distance the rocket must travel in the vertical direction relative to its static position before the rocket will ignite. The distance being measured in units of feet.

3.6 ROCKET POSITION (ROC POS).

Position of the rocket relative to the catapult. The x, y and z coordinates being given in the Catapult Coordinate System (CCS) in units of feet.

3.7 SEAT/MAN MOMENTS OF INERTIA (S/M M.I.).

The three principal components of the seat/man moments of inertia (Ixx, Iyy, Izz) in units of slug-feet**2.

3.8 AERODYNAMIC COEFFICIENTS (AERO).

The aerodynamic force and moment coefficients used to arrive at the forces and moments acting on the seat/man combination. Coefficients derived as a function of the angle of attack, Mach number and sideslip (3-dimensional model only).

SECTION 4

EXPLANATION OF THE METHODOLOGY USED IN STUDY

The following describes the methodology used and results obtained while using this methodology to identify the significant input parameters to two existing seat ejection mathematical simulation models. The methodology was also used to quantitatively measure the models' response to variations in selected input parameter values from their initial (base case) values.

4.1 GENERATION OF THE BASE CASE AND VARIED PARAMETER TRAJECTORIES

Two physically different sets of input parameters (rocket position, seat/man center of gravity, moments of inertia, etc.) were used in the study and are referenced in this report as Case 1 and Case 2. With the input parameters set to their corresponding base case values, two ejection trajectories were generated for each of the above cases by the model(s). One ejection trajectory was generated simulating a zero altitude-zero knot initial velocity ejection, the other simulating a zero altitude-600 knots initial velocity ejection. In this study, these four trajectories are referenced as the base case trajectories; namely, Case 1 at zero knot initial velocity, Case 1 at 600-knots, Case 2 at zero knot and Case 2 at 600-knots.

The eight input parameters, selected to be varied in this study, were then varied individually. Each variable was first varied from its base case value by a plus twenty percent then by a minus twenty percent, while the other input parameters were held constant at their initial base case values. An ejection trajectory was generated, via the 3-dimensional model ICARUS, for each case, velocity, percent variation and varied parameter combination - resulting in 64 ejection trajectories being generated (2X2X2X8).

4.2 FORMAT OF THE FILES CONTAINING THE TRAJECTORIES

The components of the above 64 varied parameter trajectories plus the 4 base case trajectories generated by the model were retained on separate files in the computer. The record format of the files created being: time, followed by the 3-linear spatial coordinate (x, y and z) values of the seat/man center of gravity with respect to an earth fixed coordinate system and these followed by the 3-angular rates of rotation (p, q and r) of the seat/man combination about a seat/man coordinate system with origin at the seat/man center of gravity. Each file containing approximately one thousand records, one record for each time step (.001 secs.) of the simulated trajectory.

4.3 USE OF THE FILES TO GENERATE PLOTS AND THE RESIDUAL VALUES OF THE TRAJECTORY COMPONENTS

The above files were then used as input data to two separate programs, one program being a plot program. This program was used to generate plots of the vertical and horizontal coordinates of the seat/man center of gravity. Appendix A contains the plots of the Case 1 varied parameter trajectories versus their respective base case trajectory.

The files were also processed by a second program which was especially written for this study. This program was used to compute the difference (residual value) between a given base case trajectory component profile and a corresponding varied parameter profile. The six components (x, y, z, p, q and r) of the base case trajectory profile being compared individually to their corresponding components contained in the varied parameter profile. The difference between the six component pairs being computed over the 1 second time profile.

> ($x_{base,i} - x_{var\ par,i}$, $y_{base,i} - y_{var\ par,i}$, ..., $r_{base,i} - r_{var\ par,i}$ where $i = 0, 1, 2, \ldots, 1000$ corresponding to the trajectory simulation time starting at zero, catapult ignition, being incremented every .001 secs. and terminating 1 sec. later).

The mean values and standard deviations of the six residual value vectors were then computed over selected intervals of the vectors. The intervals corresponding to the following phases of the seat/man ejection simulation:

1) Catapult ignition (time zero) to catapult separation.

2) Rocket ignition to rocket burnout.

3) Rocket burnout to drogue chute projection.

4) Drogue chute projection to 1 second of the simulation.

Using the corresponding mean value, standard deviation and the values of the residuals within a given phase of the trajectory, the residual value for each phase, trajectory component combination was then computed at the 95% confidence level $|R_{95}| = |\bar{R} + \sigma_{95}|$. The value of the residual at the 95% confidence level being defined here to mean that value of the residual which is 95% of the time greater than or equal to the value of the residuals contained within the phase or conversely is exceeded in value 5% of the time by the residual values contained in the phase.

The residual values at the 95% confidence level computed above were then tabulated by case, velocity, percent variation, trajectory component and phase. Appendix B displays the tabulated values of the residuals at the 95% level. Appendix E presents in mathematical form the equations

used to compute the above residual values.

4.4 USE OF THE RESIDUAL VALUES TO RANK THE EIGHT INPUT PARAMETERS

The tabulated residual values were then used to rank the eight input parameters with respect to the amount each parameter when varied by a plus or minus twenty percent caused the seat/man ejection trajectory to differ from its corresponding base case trajectory. An individual ranking of the eight parameters was determined for each case, velocity, percent variation, trajectory component and phase combination.

The procedure used to form the individual rankings of the eight parameters was as follows:

1) For a specific case, velocity, percent variation, trajectory component and phase combination - the parameter associated with the largest residual value - was ranked first and assigned the numerical value of 1. Then the parameter associated with the second largest residual value was ranked second and assigned the numerical value of 2. This procedure was continued until all eight parameters were ranked and assigned a numerical value corresponding to their relative position in the list.

2) This procedure was repeated for every case (2), velocity (2), percent variation (2), trajectory component (6) and phase combination (3) yielding 108 (2X2X2X6X3) numerical rankings of the eight input parameters.

The catapult phase of the trajectory was excluded from the above rankings procedure as the rocket input parameters are not used in the computation of trajectory until the very end of the phase.

4.5 COMPUTATION OF THE COEFFICIENT OF CONCORDANCE AND SPEARMAN'S RANK CORRELATION COEFFICIENT

The following correlation coefficients were then computed based upon these numerical rankings of the eight input parameters.

A Coefficient of Concordance was computed to measure the degree of overall agreement existing between the phase rankings of the variables for every case, velocity, percent variation and trajectory component combination. The possible values for the coefficient computed being in the interval of zero to one. A zero value obtained for the Concordance Coefficient indicating that the overall agreement existing among the phases as to the ranking of the parameters is no better than a random ranking of the parameters. Whereas, a value of one computed for the coefficient indicates that the phase rankings are in complete agreement with one another.

Snedecor's F-test both at the 95% and 90% level was used to test the statistical significance of the Concordance Coefficients computed. That is, an F-value to be tested was computed for each of the above Coefficients of Concordance derived from the numerical rankings. The F-value being computed as a function of the number of trajectory phase rankings combined (pooled) and their corresponding computed Coefficient of Concordance. The degrees of freedom to be used in entering Snedecor's F-tables were then computed as a function of the number of trajectory phase rankings combined and the number of items to be ranked.

Entering Snedecor's tables of F with the above derived degrees of freedom for the greater and lesser ratio estimate, each of the above computed F-values were tested at both the 90% and 95% confidence levels. If the value of F found in the tables was less than the F-value computed - than the interpretation of the Coefficient fo Concordance was significant at the confidence level indicated for the table of values entered.

At the 95% level, the interpretation of the coefficient being rather significant statistically. That is, the Concordance Coefficient being tested - does truly indicate the degree of correlation existing among the phases in ranking the parameters.

Spearman's Rank Correlation Coefficient was then computed to measure the degree of agreement existing between any two of the above phases of the trajectory. The range of possible values for this coefficient being a plus or minus one. A minus one indicating that between any two specific phase rankings of the parameters - the degree of agreement is negatively correlated - that is, the rankings of the parameters are completely the opposite of one another. A zero value indicates there is no correlation in the rankings between the two phases and finally a positive one indicating complete agreement. This coefficient was then used to determine the amount of agreement existing between the phases in forming a new ranking of the parameters based upon the combined numerical values of the individual phase rankings of the parameters. The individual component rankings of the parameters were then pooled together (within case and between cases) and new rankings of the variables were formed based upon these poolings. The corresponding Coefficient of Concordance, F-values and Rank Correlation Coefficients were computed for each pooling combination.

Appendix C presents the tabulated values of the above coefficients and F-values derived. The individual and pooled rankings of the eight parameters is also displayed in this appendix. Appendix F contains a mathematical presentation of the ranking procedure used to derive the Coefficient of Concordance and Spearman's Rank Correlation Coefficients.

SECTION 5

ANALYSIS OF THE COEFFICIENTS AND RANKINGS OF THE INPUT PARAMETERS OBTAINED FROM THE STUDY

Appendix C (Tables 1 thru 9, R1 thru R12) present the tabulated values of the Coefficients of Concordance, their corresponding F-values, Spearman's Rank Correlation Coefficients and the various rankings of the eight input parameters obtained during each step of the study. As presented in Section 4 of this report, these coefficients were computed as a function of the (individual and pooled) trajectory component numerical rankings of the parameters.

The numerical rankings of the parameters were ascertained by the amount each input parameter (when varied) disturbed the values of the trajectory components from their corresponding base case values.

5.1 INDIVIDUAL TRAJECTORY COMPONENT RANKINGS AND COEFFICIENTS

Tables 1 to 4 present the tabulation (by case, velocity and percent variation) of the correlation coefficients obtained from the individual trajectory component rankings of the eight input parameters. Tables R1 to R4 display the actual ordering of the parameters obtained from the individual numerical rankings.

An examination of the values contained in the Tables 1 thru 4 indicates there exists a relatively high correlation among the trajectory phases in the ranking of the parameters by the individual trajectory components. In addition, there is a 95% probability, except for two instances, that the overall degree of agreement indicated by the Concordance Coefficients can be accepted as being valid. The two exceptions being:

1) the numerical rankings assigned to the input parameters by the z coordinate of the trajectory in the -20% variation section of Table 2 resulted in a computed F-value of 2.55. This value was less than the F-table value of 2.92 required for the acceptance of the Coefficient of Concordance value (.56) at the 95% confidence level. However, the coefficient can be accepted at the 90% confidence level. The F-table value at this level being 2.28.
2) the numerical rankings assigned to the input parameters by the y coordinate of the trajectory in the +20% variation section of Table 2 resulted in a computed F-value of 1.44. This value of F was found not to be significant at either the 95% or 90% confidence level.

Finally, the relatively high values of the Spearman's Rank Correlation Coefficients, presented in the Tables 1 thru 4, indicates that the new rankings formed by combining the individual phase rankings of the parameters are statistically significant.

5.2 WITHIN CASE POOLED RANKINGS

Tables 5 and 6 present the correlation coefficients and corresponding F-values by case, velocity and percent variation. The values displayed in the tables were obtained by the pooling of the individual linear (x, y and z combined) and angular rate (p, q and r combined) component rankings of the input parameters. The upper and middle sections of Table 5 (Case 1) and Table 6 (Case 2) present the coefficients obtained by the within Case 1 and within Case 2 pooling of the linear and angular rankings. The lower section (0 +600) of the tables present the coefficients obtained by the further within case combining of the linear and angular rankings, this time across velocities (zero knot combined with 600 knots initial velocity).

A comparison between the values displayed in the upper and middle sections of Tables 5 and 6 and their corresponding individual component values contained in Tables 1 thru 4 indicates, as the component rankings are grouped together, the amount of agreement as to the ranking of the eight input variables tends to decrease. That is, the coefficients of Concordance and the Rank Correlation Coefficients derived from the within case, within velocity pooling of the linear and angular rankings tend to be lower in value than their corresponding individual component coefficient values found in Tables 1 thru 4. This decrease in the values of the coefficients, when the trajectory component rankings are pooled, indicates that the individual component rankings of the eight input parameters are slightly different from one another.

The lower section of Tables 5 and 6 present the values of the Coefficients obtained when the linear and angular rankings were further pooled across velocities (zero velocity combined with 600 knots velocity). A comparison between the values presented in the lower section of Tables 5 and 6 to their corresponding values contained in the upper and middle sections of the same tables indicates, the linear rankings when further pooled across velocities results in the degree of agreement in the ranking of the parameters being lowered. This was true for both Case 1 and Case 2 poolings. However, a comparison of the angular poolings across velocities to their corresponding component poolings indicates the following:

1) the combining of the Case 1's 3 angular rankings at zero velocity with Case 1's 3-angular rankings at 600 knots results in the further reduction of the correlation coefficient values relative to the values obtained for the two corresponding within velocity poolings of the coefficients.

2) the combining of the Case 2's angular rankings across velocities however, results in obtaining somewhat of an average value for the correlation coefficients.

The anomaly between the Case 1 angular component pooling across velocities and the Case 2 angular pooling across velocities can best be explained by the following rational. The weight of the seat/man combination used for the Case 1 at 600 knots initial velocity was 20% lighter than the weight of the seat/man combination used for Case 1 at zero velocity initial condition. A separate sidebar study identified the weight of the seat/man as being a significant input parameter. Therefore, in the Case 1 pooling of the angular rates across velocities, the correlation coefficients obtained reflect the effect of the difference in the seat/man weight along with the difference in velocity has upon the pooled ranking obtained. The weight of the seat/man was the same in Case 2 for both the zero and 600 knots initial velocity studies. Thus, the pooling of the linear rankings accross velocities tends to indicate, even with the difference in the weight of the seat/man combination effecting the results of the Case 1 poolings, that at different velocities the ranking of the input parameters can be different from on another. This is confirmed by the reduction in the Case 2 pooled velocity correlation coefficients obtained in this case, as was stated, the weights were the same. The values of the Concordance Coefficients shown in Tables 5 and 6 were all statistically significant at the 90% and 95% confidence levels.

The actual rankings of the eight input parameters formed at each step of the above pooling process are displayed in Tables R5 thru R8. Multiple entries in a given row/column designated cell of the tables indicates that the ranking method used assigned the same numerical ranking to the parameters displayed in the cell. As stated above, the pooling of the linear and angular rankings resulted in a reduction in the degree of agreement in the new ranking of the parameters formed, and when the rankings were further pooled (zero initial velocity combined with 600 knots initial velocity) the degree of agreement was reduced further. This suggests the actual rankings of the parameter in the upper and lower sections of Tables R5 thru R8 (the pooled linear and pooled angular rankings) are statistically less significant than the rankings of the parameters displayed in Tables R1 thru R4 (the individual trajectory component rankings). Because of low values obtained for the above pooled velocity correlation coefficients, the corresponding actual rankings of the parameters are not displayed in the tables.

5.3 BETWEEN CASE POOLED RANKINGS

Tables 7, 8 and 9, R9 thru R12 display the values of the correlation coefficients and the actual rankings of the eight input parameters obtained by pooling Case 1 and Case 2 individual component rankings.

5.3.1 Between Case Individual Trajectory Component Rankings of the Parameters Pooled. Tables 7 and 8 present the values of the coefficients obtained by combining (within velocity) the individual trajectory component rankings of Case 1 with their corresponding component rankings in Case 2:

> (the x-trajectory component rankings of Case 1 combined with the x-trajectory component rankings of Case 2, the y-trajecotry component rankings of Case 1 combined with the y-trajectory component rankings of Case 2, etc.)

A comparison of the coefficients displayed in Table 7, zero velocity, to their corresponding individual component values contained in Tables 1 and 2, indicates that the pooling of the individual linear rankings (Case 1 components combined with Case 2 components) reduces the correlation coefficient values relative to their corresponding component values found in Tables 1 and 2. However, a comparison of the individually pooled angular rate components to their corresponding components also found in Tables 1 and 2 indicates that the angular coefficient remain relatively unchanged except for the effects of data averaging which is inherent in the ranking procedure used.

A comparison of the coefficients displayed in Table 8 (obtained by pooling Case 1 and Case 2 individual linear and angular rankings of the parameters at 600 knots initial velocity) to their corresponding individual component values found in Tables 3 and 4 indicates that both the linear and angular coefficient values have been reduced in value from their corresponding individual component values found in Tables 3 and 4.

Thus, at the low velocity initial condition there is evidence that the two physically different sets of input parameters can rank the parameters differently as evidenced in the reduction of the linear coefficient values obtained when Case 1 and Case 2 were combined at zero knot. The angular rates remained relatively unchanged in this situation. However, in the high velocity pooling, both the linear and angular coefficient values were reduced from their corresponding individual component values found in Tables 3 and 4. This difference can be attributed to the differences existing between the two sets of input parameter base values used in the study (Case 1 versus Case 2) and specifically to the large difference (20%) in the seat/man weight existing between the two cases at the 600 knot initial velocity condition, whereas in the 0-knot pooling of the rankings, a five percent difference between the two corresponding seat/man weights was not so noticeable. The between case pooling of the individual component rankings of the input parameters indicates that the rankings of the input parameters can be effected by differences in the initial values of the parameters.

In several instances the Spearman's Rank Correlation Coefficients in Table 8 were slightly higher than their corresponding component values found in Tables 3 and 4. Again, this was due to the numerical averaging effect inherent in the ranking procedure used.

In all cases, the interpretation of the Coefficients of Concordance, as to the overall degree of agreement in the rankings obtained, was found to be statistically significant at the 95% confidence level.

Tables R9 and R10 present the actual component rankings of the eight input parameters obtained by combining the Case 1 and Case 2 corresponding individual component rankings. Here too, the rankings formed by pooling are statistically less significant than the rankings displayed for the individual components. (Tables 1 thru 4).

5.3.2 Between Case Linear and Angular Component Poolings. Table 9 presents the between case linear and angular component pooling (x, y and z Case 1 combined with x, y and z Case 2; p, q and r Case 1 combined with p, q and r Case 2). The coefficient values shown in Table 9 tend to be lower in value than their corresponding individual pooled component values found in Tables 7 and 8. These lower values can be attributed in some part to the effects of data averaging but, from the prior results noted for the between and within case component poolings, there is reason to suspect that the reductions are also due to the differences existing between the components in the ranking of the parameters. That is, the individual component rankings are different from one another.

Tables R11 and R12 display the actual rankings of the input parameters obtained by the between case pooling of the linear trajectory component rankings (x, y and z combined) and angular trajectory component rankings (p, q and r combined). These rankings are statistically less significant than their corresponding individual component rankings displayed in Tables R9 and R10.

5.3.3 Summary of the Results Obtained from the Ranking Procedure used in the Study. In conclusion, the preceding analysis of the individual and pooled rankings of the eight input parameters by the six trajectory components indicates the following:

1) the individual trajectory component rankings of the eight input parameters are consistent (in agreement) from phase to phase of the trajectory as indicated by the high values of the Concordance Coefficients obtained for each of the above rankings formed. In addition, these coefficients were found to be statistically significant at the 95% confidence.

2) as the component rankings are pooled together, linear component rankings combined and angular component rankings combined, the degree of agreement as to the ranking of the parameters

decreases. This is confirmed by the decrease in value of the Coefficients of Concordance and Spearman's Rank Correlation Coefficients. This implies that the individual trajectory component rankings can be different from one another.

3) the further decrease in the Concordance Coefficient and Spearman's Rank Correlation values when the trajectory component rankings of the parameters were pooled across velocities (zero velocity combined with 600 knots velocity) indicates that the ranking of the parameters obtained at zero velocity was different than the ranking of the parameters at 600 knots velocity.

4) the decrease in the values obtained for the Concordance Coefficients and Spearman's Rank Correlation Coefficients when the individual trajectory component rankings of Case 1 were combined with Case 2 indicates two physically different sets of input data can rank the variables differently from one another.

5) the weight of the seat/man was identified as being a significant factor, in addition to the initial velocity, in determining the ranking of the input parameters.

An examination of the plots (Appendix A) made of Case 1 varied parameter trajectories versus their corresponding base case trajectory and the tabulations of the residual values (Appendix B) indicates as the trajectory progresses (from catapult ignition to 1 second), the difference between the varied parameter trajectory and the base case trajectory increases.

5.3.4 Explanation of the Coded Rank Tabulations of the Input Parameters. Tables D1 and D2, contained in Appendix D, present two numerically coded tabulations. Table D1 displays a summary of the individual linear component rankings of the input parameters and Table D2 a summary of the angular component rankings of the parameters in coded form. The above coded rankings were generated using Tables R1 and R3 (Ref. Appendix C) to obtain the linear rankings and Tables R2 and R4 to obtain the angular rankings of the parameters. Tables R1 thru R4 present the individual trajectory component rankings of the parameters.

The format of the coded tabulation being an 8x8 matrix. Each of the eight columns of the matrix being assigned, and titled as such, to one of the eight input parameters selected to be studied. The rows of the matrix (numbered 1 to 8) being used to designate the relative rank of the parameters.

The numbers 1 thru 4 found, in the individual cells of the two matrices, designate the following:

1. the number 1 implies Case 1 at 0-knots initial velocity pooled ± 20% variation.

2. the number 2 implies Case 1 at 600-knots initial velocity pooled ± 20% variation.

3. the number 3 implies Case 2 at 0-knots initial velocity pooled ± 20% variation.

4. the number 4 implies Case 2 at 600-knots initial velocity pooled ± 20% variation.

Replicates of the above numbers contained in any of the row/column designated cells of the two matrices indicating the number of times that particular parameter (designated by the column heading) was assigned the rank indicated by the row number of the cell by either the x, y or z linear trajectory component (Table D1) or the p, q or r angular trajectory component (Table D2). The rank of the specific parameter, relative to the other seven parameters, being determined by the amount the parameter, when varied from its initial base case value, caused the trajectory component value to deviate from its base case value.

Tables D1 and D2 present a visual summary of the results obtained by varying the eight input parameters individually first by a plus 20%, then by a minus 20% while holding the other parameters constant at their respective base case values. An inspection of the two tables reveals the following:

1) Six of the eight input parameters were ranked first (at least once) by one of the six trajectory components. The other two were either ranked second or third one or more times. Specifically, the moments of inertia were ranked second once by one of the angular rates as indicated in Table D2. The Rocket On parameter was ranked third three times, once by one of the trajecotry linear coordinates and twice by one of the trajectory angular rates as indicated in Tabels D1 and D2 respectively.

2) the rankings of the parameters by the linear components (x, y and z) and the angular rate components (p, q and r) are different from one another.

3) the rankings of the parameters are effected by physical differences in the ejection systems being simulated.

4) the rankings of the parameters are effected by the initial velocity of the seat/man combination.

5.4 PARAMETERS VARIED SIMULTANEOUSLY

An additional, albeit very limited, analysis of two then three of the input parameters being varied simultaneously was performed. All combinations of the parameters being varied by a plus or minus twenty percent and their associated ejection trajectories were generated. The catapult and rocket time/thrust tables, base case values for the Case 1 at 600 knots, were first varied simultaneously followed by the catapult and rocket time/thrust tables plus the seat/man center of gravity being varied simultaneously.

As would be expected, certain combinations of the input parameters being varied simultaneously tended to minimize the difference between the varied parameter trajectory obtained and its corresponding base case trajectory, while other combinations tended to maximize the difference.

Appendix A, (figures A-19 thru A-24 show) the trajectories obtained by the simultaneous varying of the above parameters along with their corresponding base case trajectory.

5.5 SPECIAL CASES SHOWING THE EFFECT OF VARYING ALL EIGHT PARAMETERS SIMULTANEOUSLY

Two special cases (Case 1 at 0-knot and Case 1 at 600-knots initial velocity) were devised whereby the eight input parameters were varied by small amounts simultaneously. The two trajectories obtained (one for the 0-knot, the other for the 600-knots initial velocity condition) by varying the eight parameters by small amounts deviated from their corresponding base case trajectories almost as much as the maximum deviation obtained by varying the parameters individually by ± 20%.

Appendix A, (figures A-25 and A-26) show the above varied parameter trajectories along with their respective base case trajectory.

SECTION 6

RECOMMENDATIONS

Because of the near infinite number of possible combinations of the input parameter values attainable by varying them simultaneously anywhere from zero to a plus or minus twenty percent, an exhaustive case by case study of the parameter interaction terms would be impractical. If a more indepth analysis of the simulation model's response to varying specific or all of the input parameters simultaneously by the same or different amounts is required, a stochastic approach might be considered, The fact that all of the input parameters' base case values have some degree of uncertainty associated with them supports this type of approach being taken.

6.1 OUTLINE OF THE STOCHASTIC APPROACH

The stochastic approach was not used for this effort due to very high projected computer cost, however, it would be possible to allow the user of the model(s) to enter the parameters to sampling distributions. These distributions would then be used to obtain the model's input parameter values. The actual values of the input parameters being randomly generated from their respective sampling distribution. An ejection trajectory would then be generated, via the model, based upon these randomly generated values of the input parameters. The random input parameter values and ensuing trajectory generation would be repeated n-times. After n-iterations, an envelope of trajectories surrounding the base case trajectory would be generated. Once the proper sample size (n) is ascertained, the boundaries (or near boundaries) of the envelope should be among the (n) trajectories generated.

Thus, based upon the user's best estimate as to the degree of variability existing around each input parameter, the maximum expected difference between the base case trajectory (generated using the most likely values of the input parameters) and the n-randomly generated trajectories should be ascertained.

Figures 1 to 4 display the envelope surrounding each of the four base case trajectories (Case 1 and 2 at zero and 600 knots respectively). The envelopes reflect the bounds of the trajectories generated by varying the parameters individually by a plus or minus 20%.

TRAJECTORY ENVELOPE

CASE 1, 0 KNOT

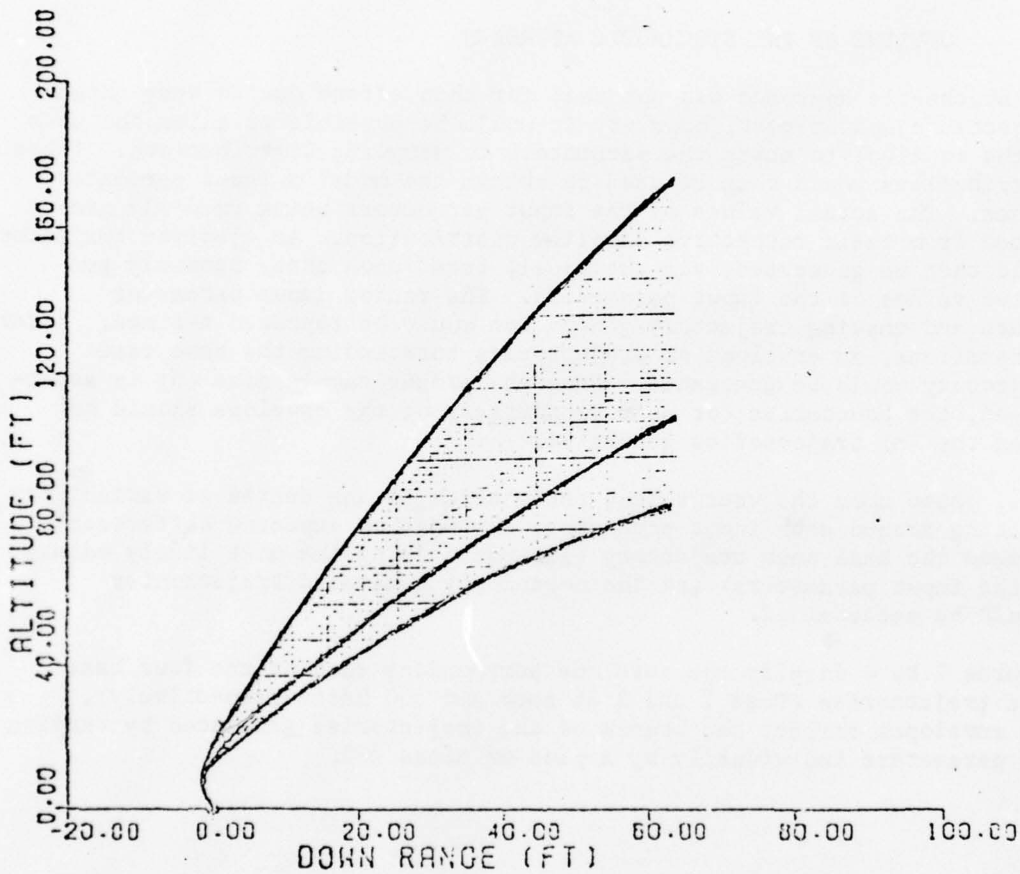


Figure 1

TRAJECTORY ENVELOPE

CASE 1, 600 KNOTS

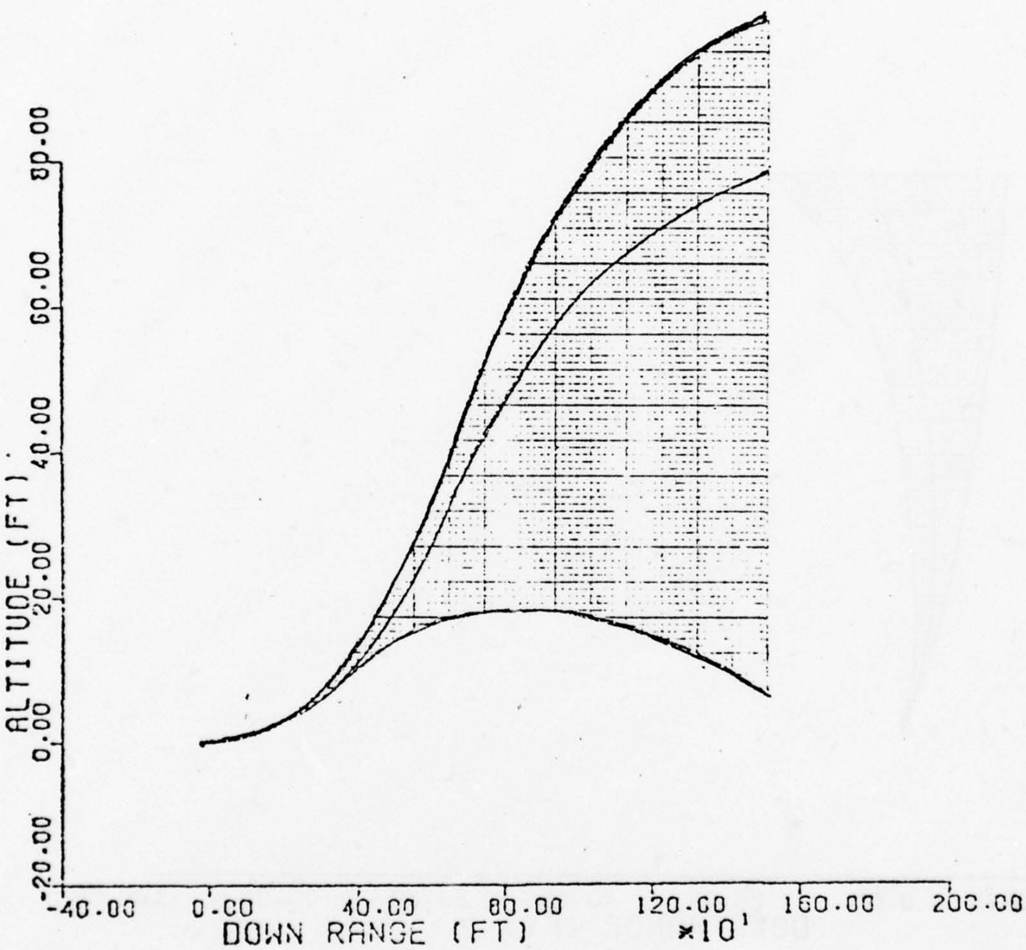


Figure 2

TRAJECTORY ENVELOPE

CASE 2, 0 KNOT

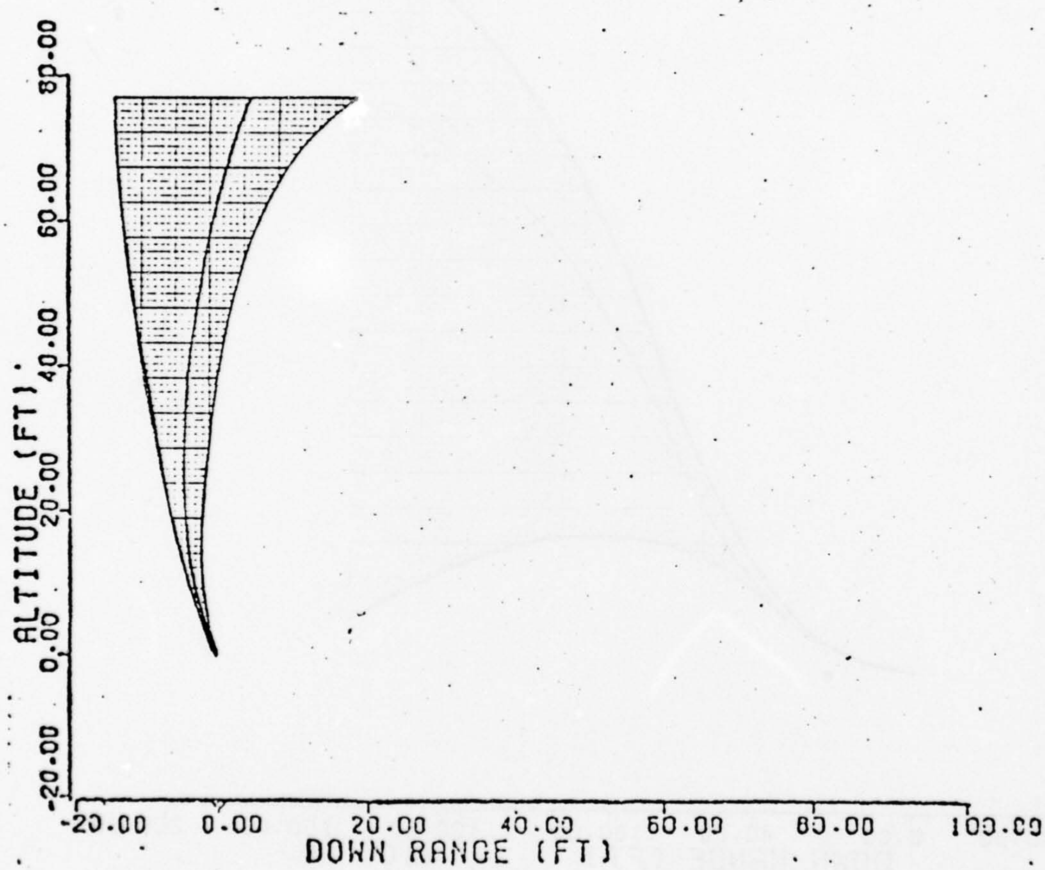


Figure 3

TRAJECTORY ENVELOPE

CASE 2, 600 KNOTS

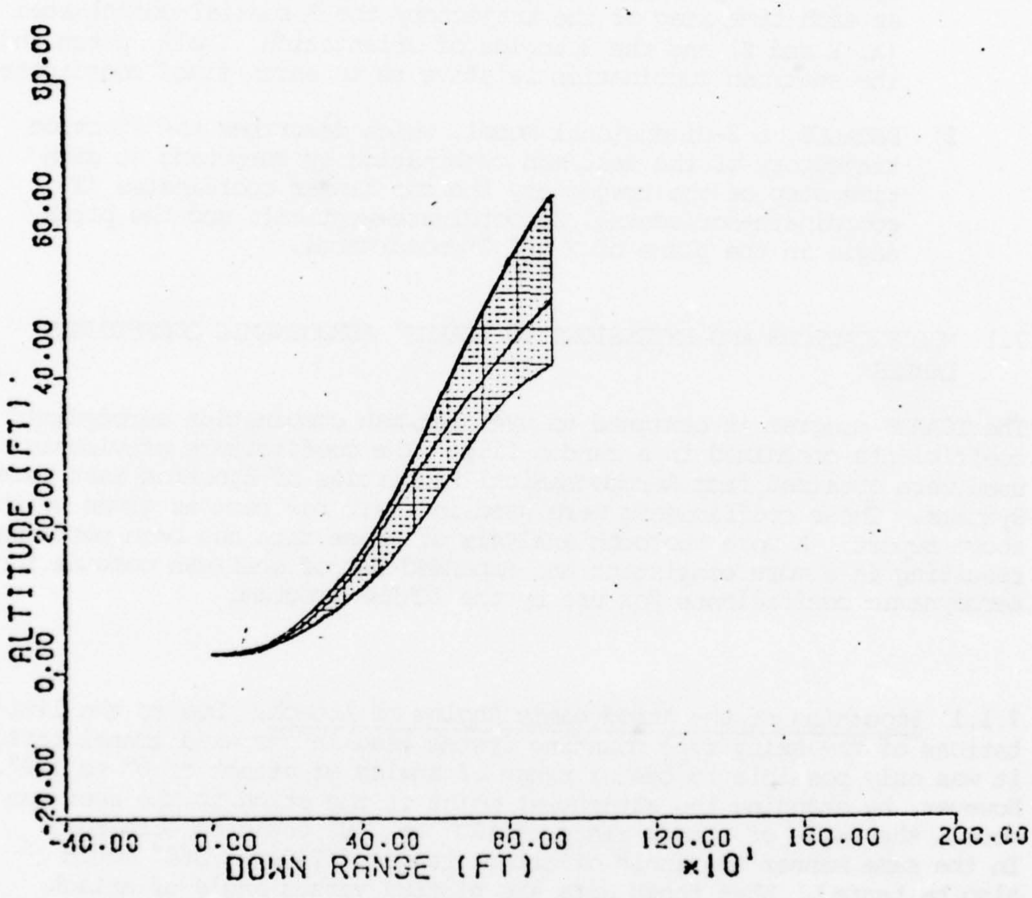


Figure 4

SECTION 7

DOCUMENTATION OF THE LATEST REVISIONS TO THE ICARUS AND DEDALUS SEAT EJECTION MODELS

The following documents the work completed to date by Computer Sciences Corporation in modifying and extending the capabilities of two seat ejection mathematical simulation models, namely:

1) ICARUS, a 3-dimensional model which completely describes the ejection trajectory of the seat/man combination by computing at each time step of the trajectory the 3 spatial coordinates (X, Y and Z) and the 3 angles of orientation (roll, pitch and yaw) of the seat/man combination relative to an earth fixed coordinate system.

2) DEDALUS, a 2-dimensional model, which describes the ejection trajectory of the seat/man combination by computing at each time step of the trajectory the two linear coordinates (X coordinate-horizontal, Z coordinate-vertical) and the pitch angle in the plane of X and Z coordinates.

7.1 MODIFICATIONS AND EXTENSIONS TO ICARUS' AERODYNAMIC COEFFICIENT TABLES

The ICARUS program is designed to use seat/man combination aerodynamic coefficients contained in a random file. The coefficients previously used were obtained from Aeromechanical Properties of Ejection Seat Escape Systems. These coefficients were used in their raw form as given by the above report. A more thorough analysis of these data has been performed resulting in a more consistent and expanded set of seat/man combination aerodynamic coefficients for use by the ICARUS program.

7.1.1 Smoothing of the Aerodynamic Angles of Attack. Due to the limitations of the sting type mounting system used in the wind tunnel test, it was only possible to test a range of angles of attack of 0° to 120°. However, by changing the attachment point of the sting to the seat/man model, the angle of attack range of 120° to 240° could be obtained. In the same manner the angle of attack range of 240° to 360° could also be tested. When these data are plotted versus angle of attack the influence of the new sting location relative to the seat/man model shows up as a jump in coefficient magnitude at angles of attack of 0°, 120°, and 240°. Since the true coefficient values should be between these two levels of magnitude, a median fairing line was drawn between the coefficients at these angles of attack. Also, a best approximation fairing line was drawn through all the raw data points for the full angle of attack range. This analysis results in a smoothed set of aerodynamic

1. White, B.J., "Aeromechanical Properties of Ejection Seat Escape Systems", AFFDL-TR-74-57, April 1974

coefficients and these curves were then read at the desired angles of attack to obtain the aerodynamic coefficients versus angle of attack. These tabulated points were then plotted versus Mach number and angle of sideslip. These plots were then read at the desired Mach numbers and angles of sideslip to yield the complete set of aerodynamic coefficients to be used by the ICARUS program.

7.1.2 <u>Extension of ICARUS Aerodynamic Sideslip Coefficient Tables for Sideslip.</u> The previous version of the ICARUS program was not designed to handle aerodynamic coefficients for a full range of sideslip angles. Since the raw data from the wind tunnel test only included sideslip angles of 0° to 45° an estimate was made for the aerodynamic coefficients for sideslip angles of 45° to 90°. If sideslip angles greater than 90° were generated by the ICARUS program the run was terminated.

The aerodynamic coefficients from the wind tunnel test are in the Seat/Man Coordinate System which are fixed to the seat/man combination. Therefore, the aerodynamic coefficient at any angle of attack (α) and sideslip angle (ψ) is duplicated at the following orientation:

$$\alpha' = \alpha + 180^\circ$$
$$\psi' = 180^\circ - \psi$$

Using this relationship, a plot of coefficients versus sideslip angles of 0° to 45° and 135° to 180° can be made. This plot can then be interpolated to obtain coefficients in the 45° to 135° sideslip angle range.

Due to the limitations of its design the ICARUS program will never generate a sideslip angle greater than 90°. If the ICARUS simulation run physically tries to rotate past a sideslip angle of 90° the angle of attach and sideslip angle are calculated so as to have the same coefficient as if it had a sideslip angle greater than 90°. Therefore, it was only necessary to expand the aerodynamic coefficient tables to include sideslip angles of 0° to 90°. This was done using data from the previously described plots of coefficients versus sideslip angles. The subroutine SEATMAN was changed to remove the restrictions on sideslip angle since there are none with the use of the modified aerodynamic coefficient tables. It was also necessary to modify subroutine ACT in order to handle the increased size of these expanded aerodynamic coefficient tables.

7.2 MODIFICATIONS AND EXTENSIONS TO ICARUS' ATMOSPHERIC DENSITY, SPEED OF SOUND, AND MACH NUMBER CALCULATIONS.

The ICARUS program was modified so that it would calculate the atmospheric density, speed of sound, and object Mach number for a specified pressure and temperature rather than the previously assumed standard day conditions.

The atmospheric conditions are defined by the ambient pressure and temperature existing at the time and point of the ejection. The subroutine INPUT was modified to accept the pressure (PMBS) in milibars and the temperature (TFAR) in °F as items 13 and 14 of section 3 of the input data file. Subroutine INIT was expanded to calculate constant parameter values based on the given temperature and pressure. Subroutine SEATMAN was changed to calculate the atmospheric density, speed of sound, and object Mach number for each iteration of the ejection trajectory.

The constant values calculated by subroutine INIT are as follows:

Given: P_{amb} = Ambient pressure in milibars

T_{amb} = Ambient temperature in degrees Fahrenheit (°F)

Calculate: T'_{amb} = Ambient temperature in degrees Rankine (°R)

$= T_{amb} + 459.688$

H_p = Pressure altitude in feet for Pamb

$$= \frac{1-\left(\frac{Pamb}{1013.25}\right)^{0.19}}{0.00006875}$$

When the above H_p >36089 feet it must be recalculated by:

$$H_p = -\ln\left(\frac{\left(\frac{Pamb}{1013.25}\right)}{0.2234}\right) 20787 + 36089$$

T_{std} = Standard day temperature in °R at H_p

$= 518.688 - (0.003566\ H_p)$ when $H_p \leq 36089$

$= 390.0$ when $H_p > 36089$

ΔT = Temperature deviation from standard in °R at H_p

$= T'_{amb} - T_{std}$

For each iteration during the ejection trajectory subroutine SEATMAN calculates the corresponding atmospheric density, speed of sound, and object Mach number as follows:

Given: V = Current object velocity in feet/second

Calculate: ΔH = Change in trajectory height in feet

$= H - H_{last}$

H_p = Current pressure altitude in feet

$= H_p + \Delta H$

T_{std} = Standard day temperature in °R at H_p assuming a standard day lapse rate
= $518.688 - (0.003566\ H_p)$ when $H_p \leq 36089$
= 390.0 when $H_p > 36089$

T'_{amb} = Ambient temperature in °R at H_p
= $T_{std} + \Delta T$

P_{std} = Standard day pressure in milibars at T_{std}

$$= 1013.25 \left(\frac{T_{std}}{518.688}\right)^{5.256} \quad \text{when } H_p \leq 36089$$

$$= \frac{1013.25 \times 0.2234}{2.71828^{\lambda}} \quad \text{when } H_p > 36089$$

$$\text{where } \lambda = \frac{H_p - 36089}{20787}$$

ρ = Atmospheric density in slugs/feet^3 at H_p and T_{amb}

$$= 0.0023769 \left(\frac{P_{std}}{1013.25}\right)\left(\frac{518.688}{T_{amb}}\right)$$

V_s = Speed of sound in feet/second at H_p and T_{amb}

$$= 49.0212\sqrt{T_{amb}}$$

M = Mach number of the object at H_p, T_{amb}, and V

$$= \frac{V}{V_s}$$

7.3 MODIFICATIONS AND EXTENSIONS TO ICARUS' SEAT/MAN INITIAL PARTIAL EXPOSURE CALCULATIONS.

7.3.1 Definition of the Partial Exposure Input Paramters. The ICARUS program has been modified to use additional input parameters in an effort to more accurately define the aerodynamic forces and moments on the seat/man combination while it is moving out of the cockpit during the initial phase of the ejection sequence. Parameters were added to account for the shielding effect of the windscreen or any piece of equipment, the exposed area of the seat/man combination due to crew position within the cockpit, and the varying aerodynamic forces and moments acting on the seat/man combination during the ejection sequence until the cockpit has beem cleared.

Subroutine INPUT was modified to accept the following parameters as items 35 through 40 of section 7 of the input data file.

CREW - Crew member being ejected
0 = Pilot
1 = MCO

TRAVEL - The height (bottom of boots to top of seat) of the seat/man combination in feet.

SCREN0 - The distance in feet that the pilot has to travel before being exposed to the airstream.

SCREN1 - The distance in feet that the MCO has to travel before being exposed to the airstream.

SUN - The exposed area in square feet of the seat/man combination installed in the cockpit.

CPCG - This parameter defines the point at which the transition is made from estimated aerodynamic moments to fully exposed aerodynamic moments. It is the ratio of partially exposed area to fully exposed area at which the aerodynamic pitching moment will be 0.

Also, subroutine INPUT was modified to accept the following parameters as items 74 through 76 of section 2 of the input data file.

XCP, YCP, ZCP - The X, Y, and Z coordinates in inches of the estimated center of pressure applicable when the seat/man combination first enters the airstream.

Refer to Figure 5 for a description of these parameters.

7.3.2 Explanation of the Partial Exposure Logic and Equations Implemented in ICARUS. As the ejection sequence is executed the seat/man combination will progress from its initially shielded or partially exposed position until it is fully immersed in the airstream. Once this occurs, the fully exposed aerodynamic coefficient and areas may be used to calculate the aerodynamic forces and moments acting on the seat/man combination. However, prior to this event it will be necessary to estimate the aerodynamic forces and moments acting on the seat/man combination while it is influenced by the cockpit configuration, since the fully exposed aerodynamic coefficients and areas are not applicable to this situation.

At the time of ejection initiation the seat/man combination will be shielded from the airstream or will be exposed to some extent depending on the crew position and cockpit configuration. For the shielded case (SCREN0 or SCREN1) the seat/man combination must move a finite distance before it enters the airstream and aerodynamic forces and moments are developed. However, the partially exposed (SUN) seat/man combination already has aerodynamic forces and moments acting

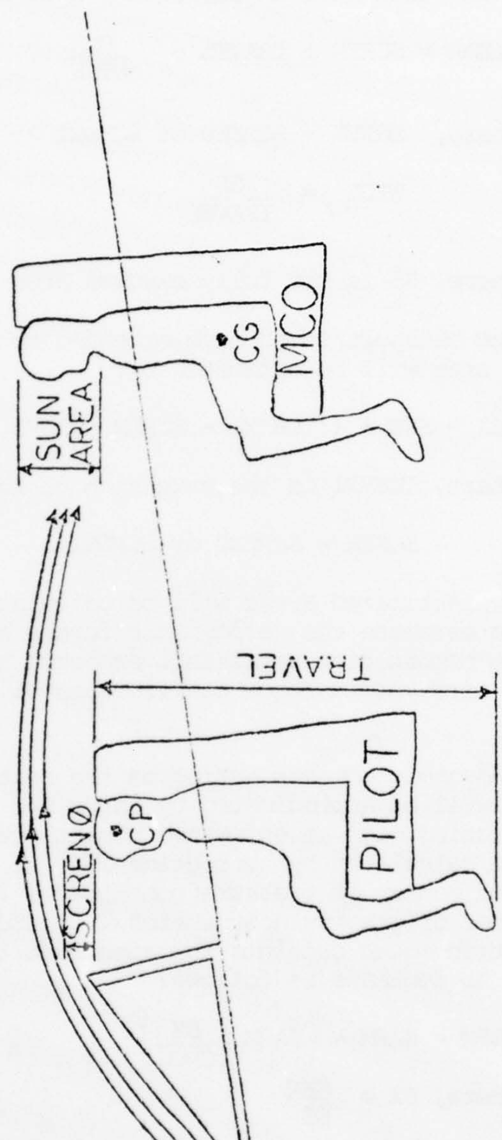


Figure 5

on it at the time of ejection initiation. Therefore, for either case the catapult tubes must extend some fixed distance for the seat/man combination to be fully immersed in the airstream. This distance (CLEAR) is determined in subroutine INIT by:

$$\text{CLEAR} = \text{SCREN} + \text{TRAVEL} - \frac{\text{SUN}}{\text{WIDE}}$$

where, SCREN = SCREN0 or SCREN1

$$\text{WIDE} = \frac{\text{SS}}{\text{TRAVEL}}$$

where, SS is the fully exposed area

Until the catapult tubes have extended to equal CLEAR the partially exposed area will be estimated by:

$$\text{SEX} = \text{SUN} + ((\text{TUBEX1} - \text{SCREN})\ \text{WIDE})$$

where, TUBEX1 is the extension of the tubes

SCREN = SCREN0 or SCREN1

The above estimated areas will be calculated by subroutine AEROFM in order to estimate the aerodynamic forces acting on the partially exposed seat/man combination until full exposure has been achieved. The fully exposed aerodynamic force coefficients will be used regardless of exposure.

The aerodynamic moments acting on the seat/man combination while partially exposed will be approximated by using the above estimated aerodynamic forces acting over an estimated moment arm. The initial estimated moment arms are calculated by subroutine INIT as the difference between the estimated center of pressure coordinates (XCP, YCP, ZCP) and the seat/man center of gravity coordinates (XCS, YCS, ZCS). As the seat/man combination moves out into the airstream the Z moment arm will be assumed to decrease as follows:

$$\text{ZARM} = \text{ZARM} - \left(\text{ZARM}\left(\frac{\text{SX}}{\text{CPCG}}\right)\right)$$

where, $\text{SX} = \frac{\text{SEX}}{\text{SS}}$

From the above equation, the Z moment arm will be reduced to 0 when SX = CPCG. Beyond this point the fully exposed aerodynamic moment coefficient will be used.

Subroutine AEROFM checks to see if the tube extension is greater than SCREN (SCREN0 or SCREN1). If not, then the exposed area is set to 0 and therefore aerodynamic forces and moments of 0 will be calculated.

When the tube extension is greater than SCREN a check is made to see if the tube extension is greater than CLEAR. If so, the fully exposed area is used. Otherwise, the estimated exposed area is calculated and used.

The following input parameter values are illegal conditions and will result in an error message and termination of the run:

(SCREN0 or SCREN1) >0 and SUN >0

(YCP - YCS) >TRAVEL

CLEAR >(TUBLTH1 + TUBLTH2)

(SCREN0 or SCREN1) >TRAVEL

SUN >SS

CPCG >1.0

7.4 REVISIONS TO BOTH DEDALUS' AND ICARUS' SIMULATION OF THE MARTIN-BAKER CATAPULT TUBE BENDING AND SEAT BOTTOM FORCES.

The following documents the latest revisions made to both the DEDALUS and ICARUS seat ejection models with respect to the simulation of the Martin-Baker Catapult.

7.4.1 Replacement of the Martin-Baker Tube Bending Equations with a Spring Equation. The tube bending equation, originally entered into both the DEDALUS and ICARUS seat ejection models to simulate the forces and moments acting on the seat/man combination as the catapult tubes extend, have been replaced with a spring equation of the form

$$F_{tube} = \{1 - \left(r/\lambda\right)^{p}\} \; \{k\Delta D + C\Delta D\}$$

where, ΔD is the resultant distance that the tube has bent forward or backward ($\pm X$ - direction) and moved sideways (yawed, $\pm Z$ direction) in the catapult coordinate system relative to its initial static position.

R is the length the tube(s) have extended since catapult ignition.

λ is the total length of the fully extended catapult.

p is an empirically fitted constant.

k is the stiffness constant (pounds/feet)

c is the damping coefficient (pounds-second/feet)

F_{tube} is the resultant force (lbs.) acting on the seat/man combination due to the tube bending.

A friction force due to the tube bending is also computed as well as the components of the F_{tube} force. The tube bending force is computed in the catapult coordinate system and transformed to the seat/man coordinate system. The calculation of this force is ended once tube separation occurs.

7.4.2 Insertion of a Seat Bottom Restoring Force. A restoring force is computed at the bottom of the seat which prevents the seat from moving through the tube. If X is the distance that the bottom of the seat has traversed through the tube in the plane perpendicular to the tube then the magnitude of this force, F, is given by

$$F = -KX$$

where K is the stiffness constant. The calculation of this force is completed once the bottom slippers have cleared the top of the rail.

7.5 MODIFICATIONS AND EXTENSIONS TO DEDALUS' ATMOSPHERIC DENSITY, SPEED OF SOUND AND MACH NUMBER CALCULATIONS.

The DEDALUS program has been modified to include the effect of the local pressure and temperature on the atmosphereic density and speed of sound used in the aerodynamic force and moment calculations.

Subroutine INPUT was altered to accept the following atmospheric parameters from the input data file:

- Atmospheric temperature in degrees Fahrenheit (^{O}F)

PMBS - Atmospheric pressure in milibars

Subroutine INPUT was changed so that the atmospheric density and speed of sound will be calculated based on the input pressure and temperature. The atmospheric density and speed of sound remain constant throughout the trajectory and are not corrected for changes in altitude. The equations are:

T_{amb} = Ambient temperature in degrees Rankine (^{O}R)
= + 459.688

V_s = Local speed of sound in feet/second
$= 47.02\sqrt{T_{amb}}$

ρ = Atmospheric density in slugs/feet^3
$= 0.002379\left(\frac{PMBS}{1013.25}\right)\left(\frac{518.688}{T_{amb}}\right)$

7.6 REPLACEMENT OF DEDALUS AERODYNAMIC COEFFICIENT CURVE FITTED EQUATIONS WITH AERODYNAMIC COEFFICIENT TABLES.

The method of providing the seat/man combination aerodynamic coefficients for the DEDALUS program has been modified. Previously, subroutine AERSEAT contained curve fitted equations based on the raw test data from Aeromechanical Properties of Ejection Seat Escape Systems. These curve fitted equations were then used to calculate the coefficients for a given Mach number and angle of attack. Due to the errors inherent in trying to curve fit these aerodynamic coefficient data it was decided to revert to a table presentation of the aerodynamic coefficients. The curve fitted equations of subroutine AERSEAT were replaced with DATA statements containing the coefficients as a function of angles of attack and Mach numbers. These tables are interpolated to obtain the coefficients for the desired Mach number and angle of attack.

7.7 IMPLEMENTATION OF A SUMMARY OUTPUT REPORT INTO DEDALUS.

The DEDALUS program was modified to provide the printing of a summary report. The existing trajectory report, aerodynamic report and catapult reports can now be selected as options.

The summary report will always be output and consists of events only. Each time an event occurs the appropriate message is printed along with time, horizontal distance, vertical distance, pitch angle, Mach number, horizontal velocity, and vertical velocity. The optional reports can be printed by setting the following input data file flags to 1.

INTRAJ - Print trajectory report
IAERO - Print aerodynamic report
IOPT - Print catapult reports

Setting any of these flags to 0 will surpress that report.

7.8 IMPLEMENTATION OF A SUMMARY OUTPUT REPORT INTO ICARUS

The ICARUS program was modified to provide the user of the model with the option of printing a summary output report in addition to or in lieu of the existing detailed trajectory output reports. The report displays time, the components of the seat/man acceleration, velocity, linear position and angular velocity and the rotation angles used to rotate from the seat/man coordinate system to the earth fixed coordinate system. The above variables are displayed in truncated form with 1 digit after the decimal point being retained.

Location 25 of the IRSW vector contained in the CARDIN file is used to control the generation or to inhibit the generation of this report. Setting IRSW (25) to:

0 - will inhibit the generation of the summary report while having no effect on the other reports requested by the user of the model.

1 - will cause the model to generate and output the summary report and to inhibit the generation of the detailed reports if any have been requested.

2 - will cause the summary report to be generated and outputted in addition to the other reports requested by the user of the model.

APPENDIX A

PLOTS OF THE TRAJECTORIES

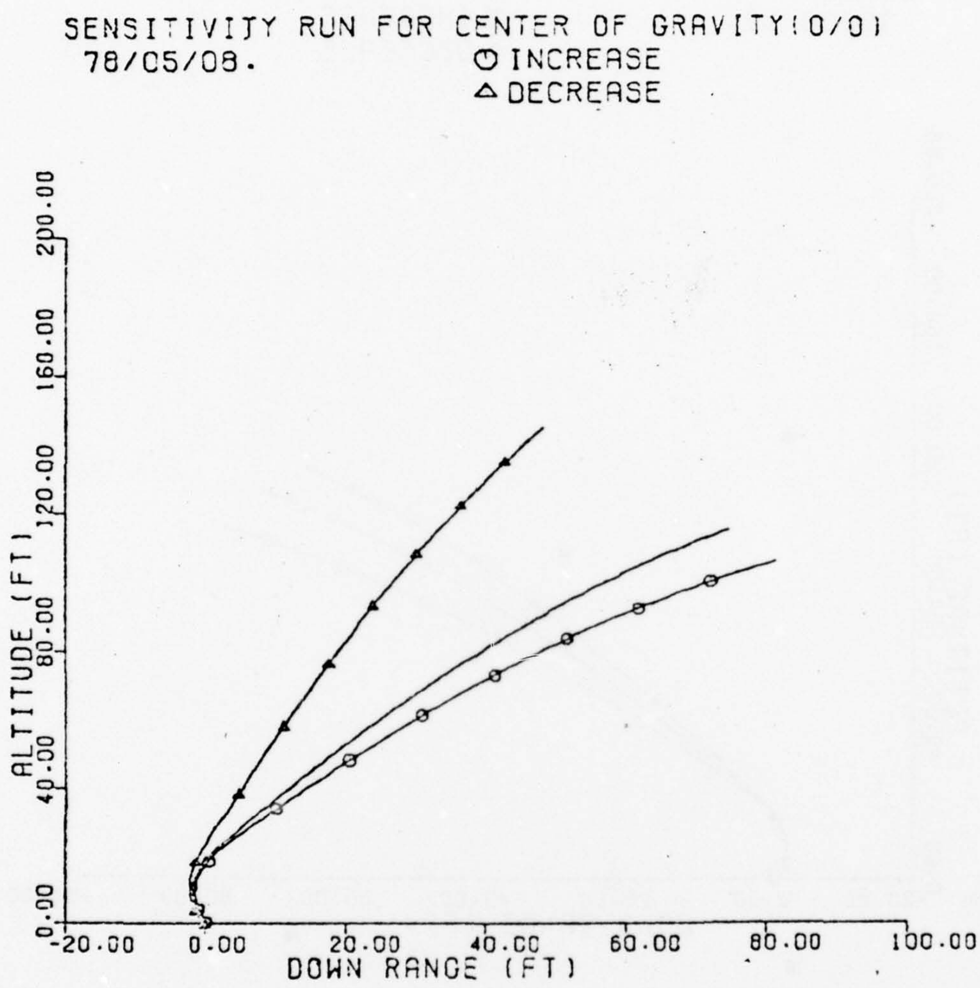

SENSITIVITY RUN FOR CENTER OF GRAVITY(0/0)
78/05/08.
INCREASE
DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-1

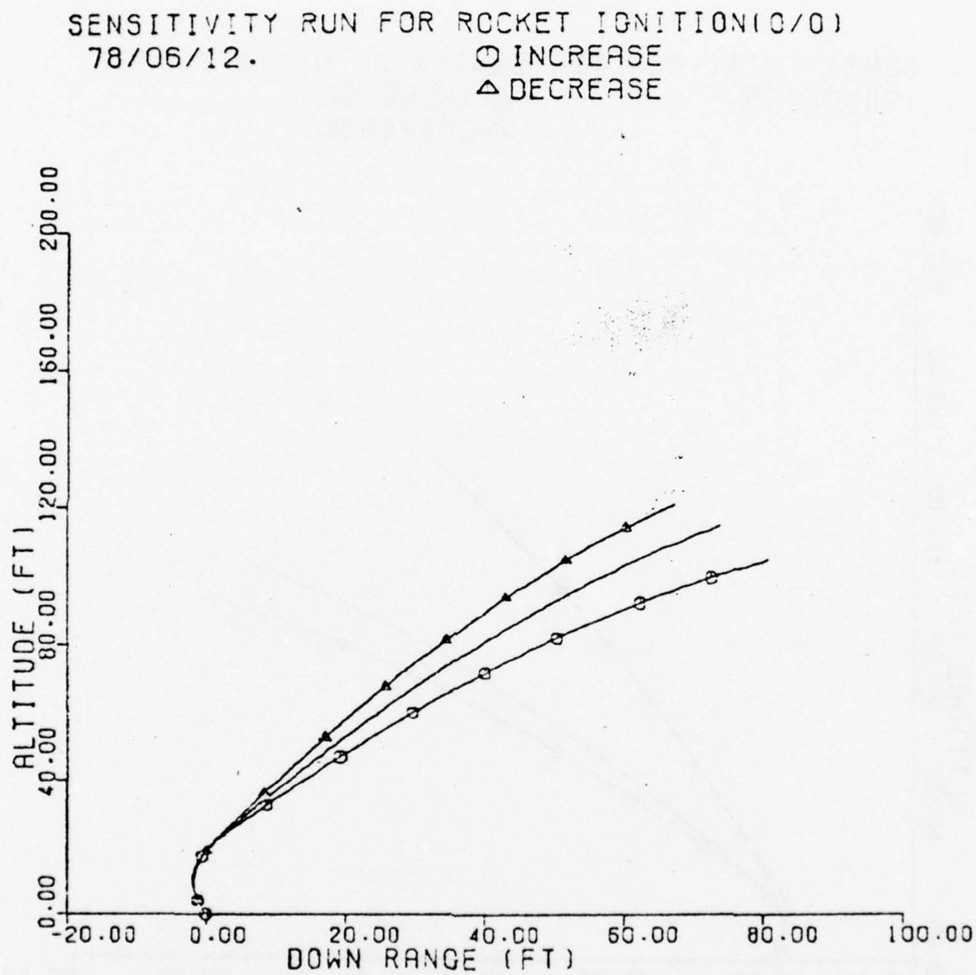

SENSITIVITY RUN FOR ROCKET IGNITION(0/0)
78/06/12.
INCREASE
DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-2

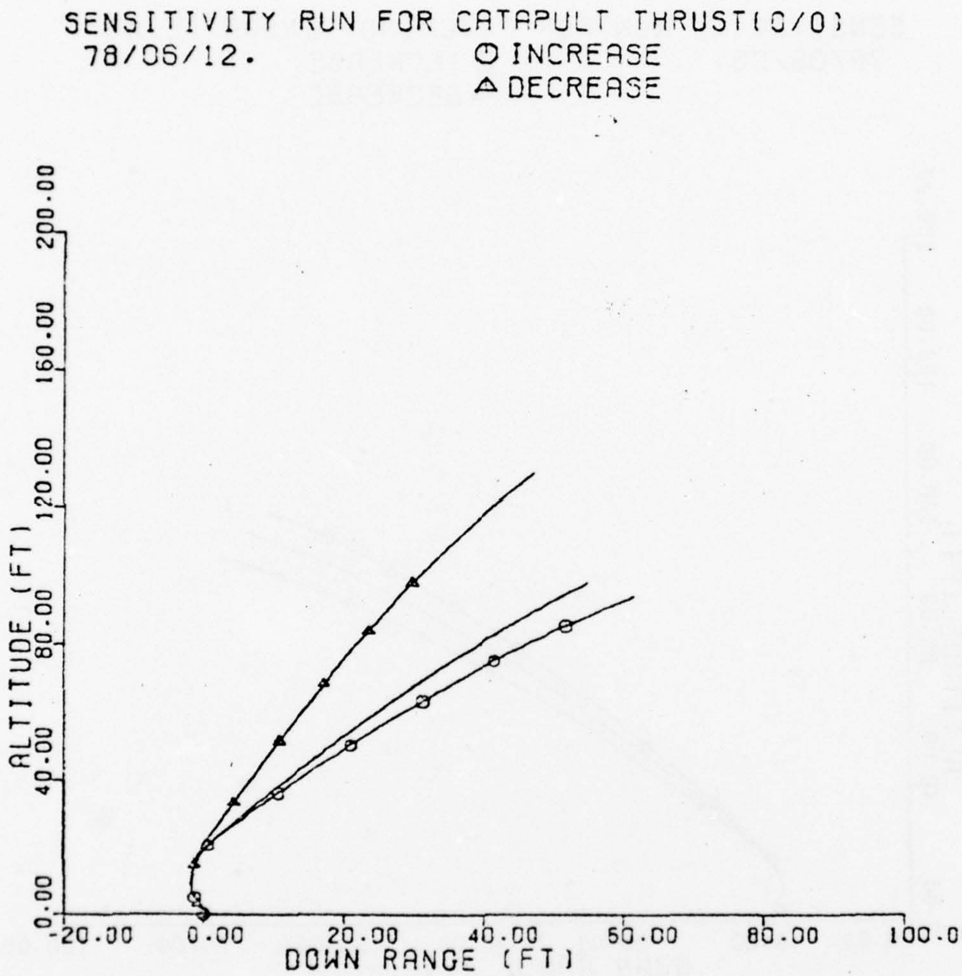

SENSITIVITY RUN FOR CATAPULT THRUST(C/O)
78/06/12.
O INCREASE
△ DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-3

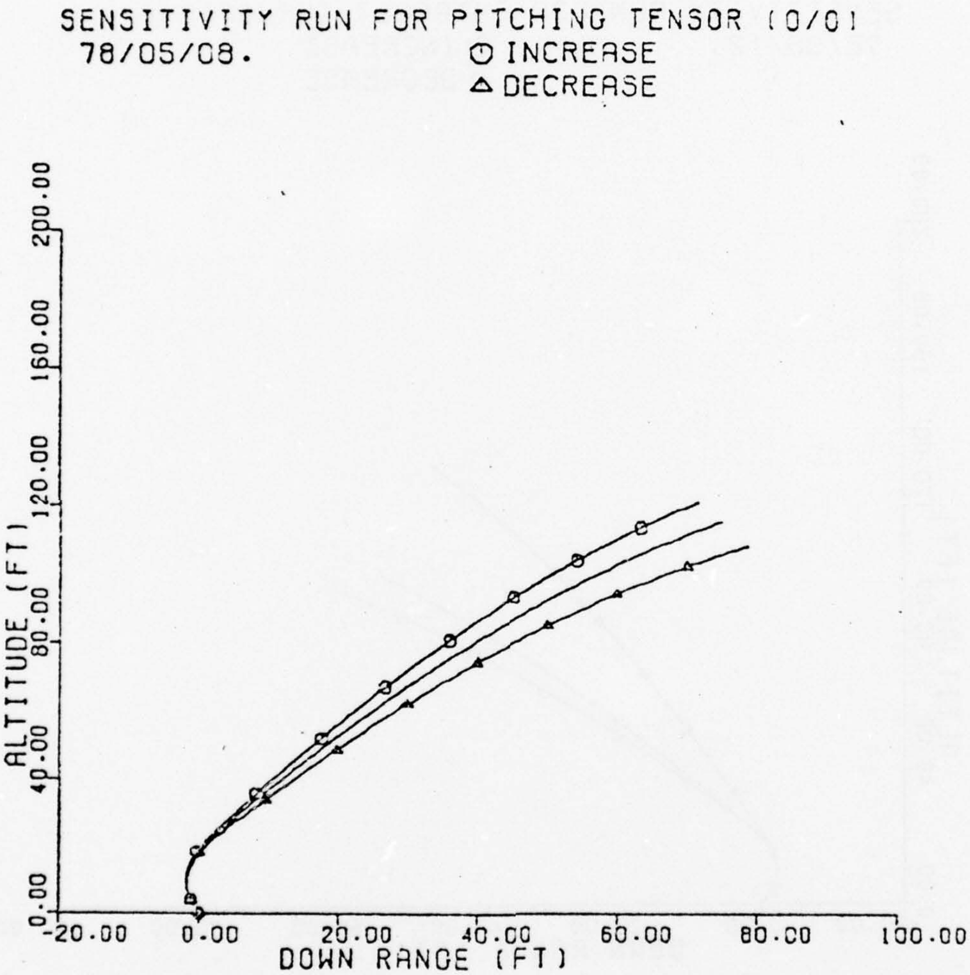

SENSITIVITY RUN FOR PITCHING TENSOR (0/0)
78/05/08.
INCREASE
DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-4

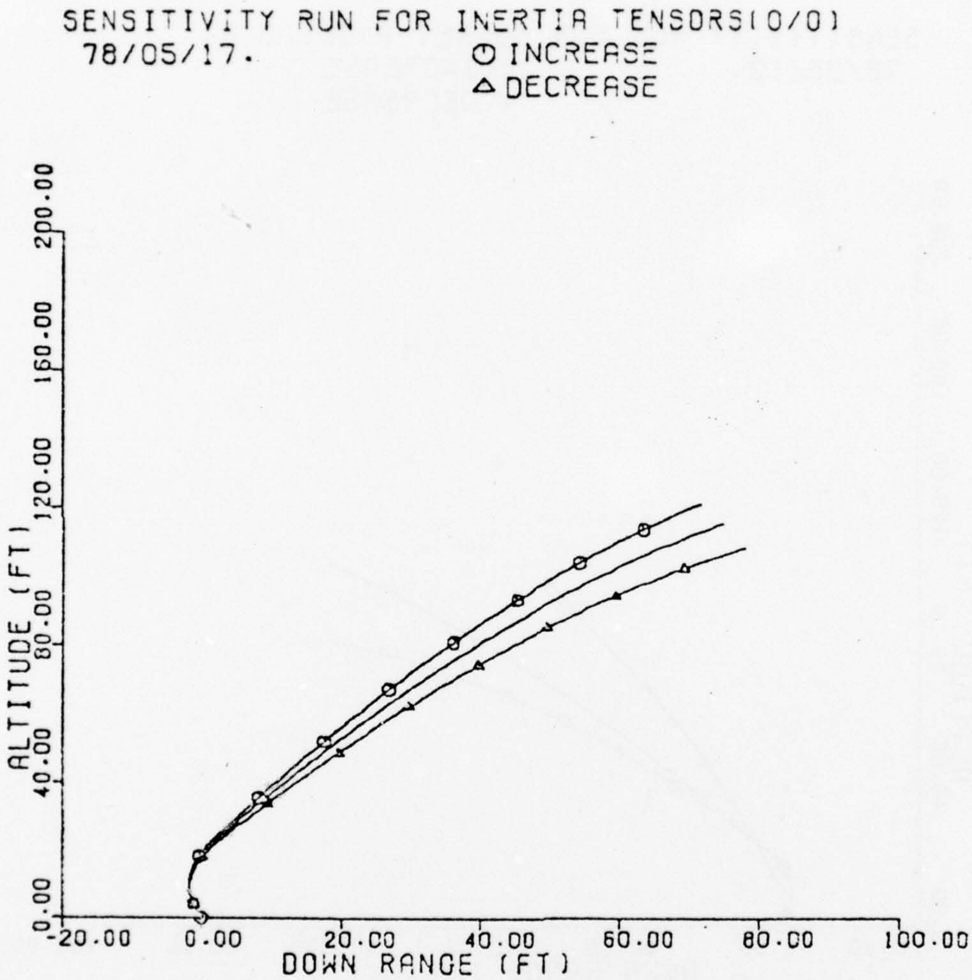

SENSITIVITY RUN FOR INERTIA TENSORS(0/0)
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-5

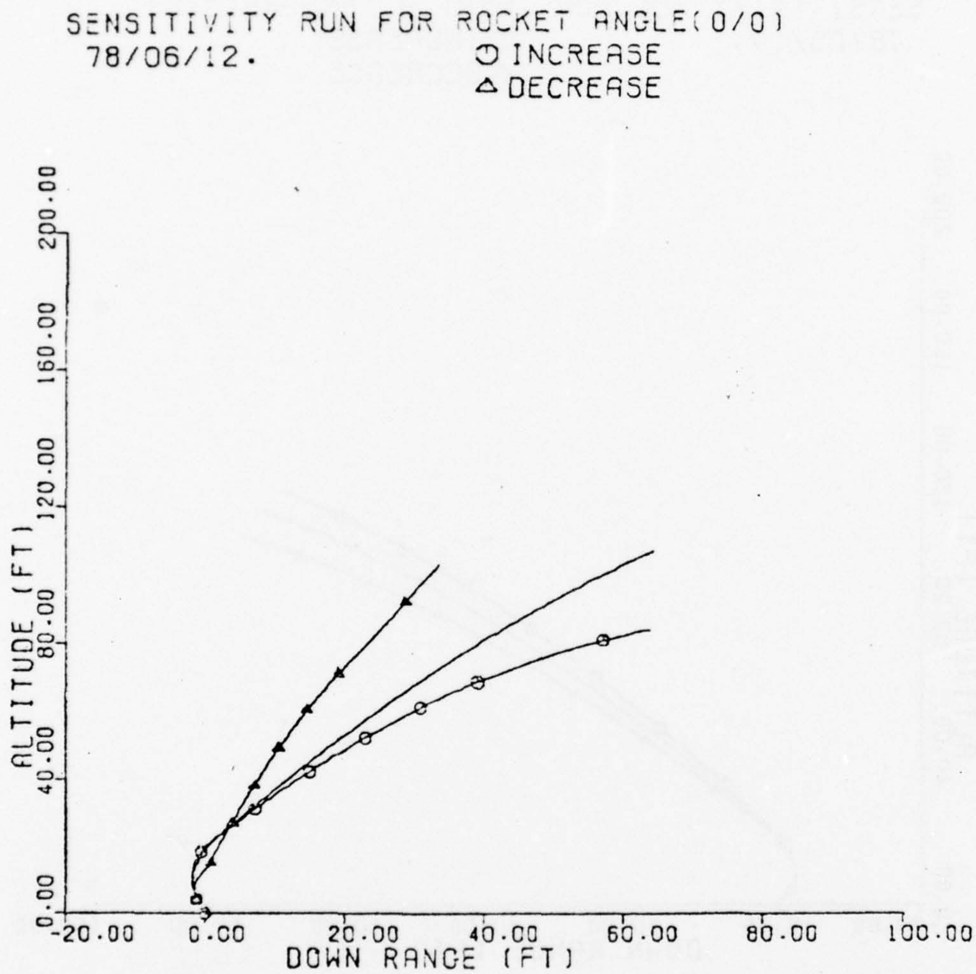

SENSITIVITY RUN FOR ROCKET ANGLE(0/0)
78/06/12.
INCREASE
DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-6

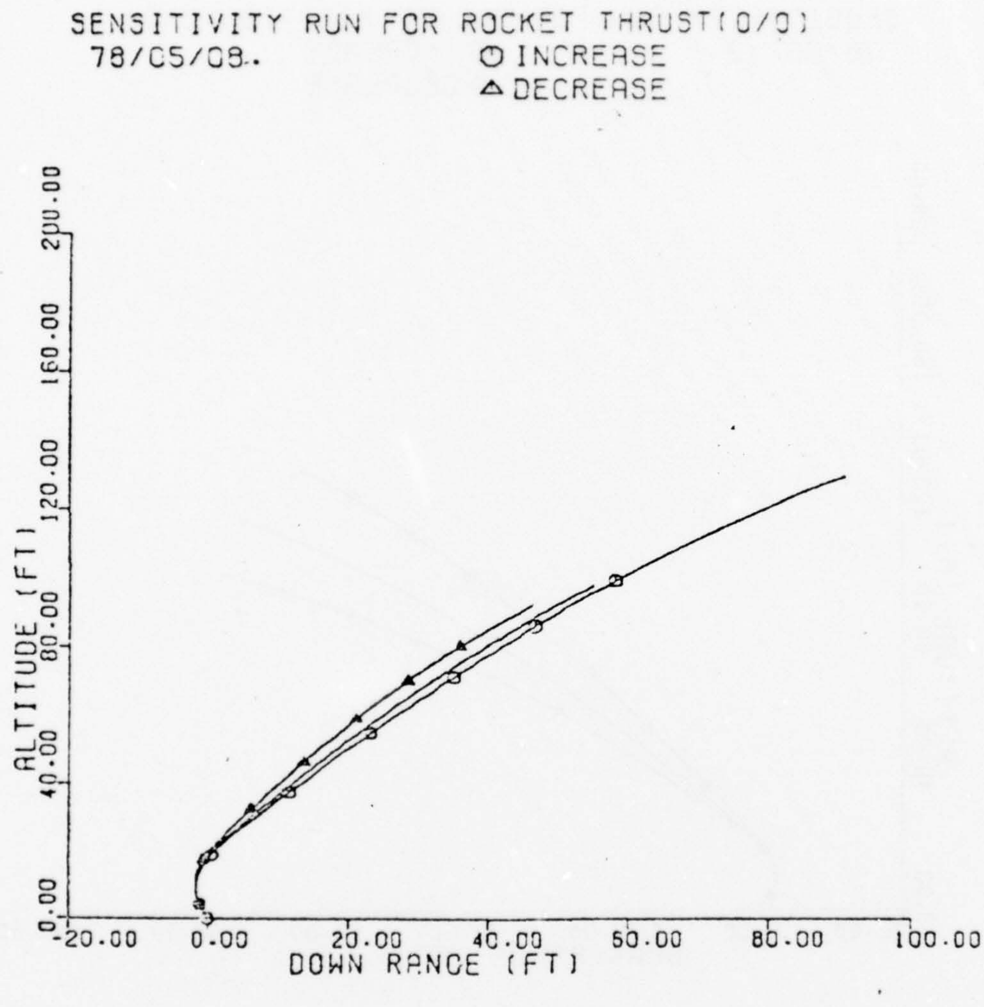

SENSITIVITY RUN FOR ROCKET THRUST(0/0)
78/05/08.
INCREASE
DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-7

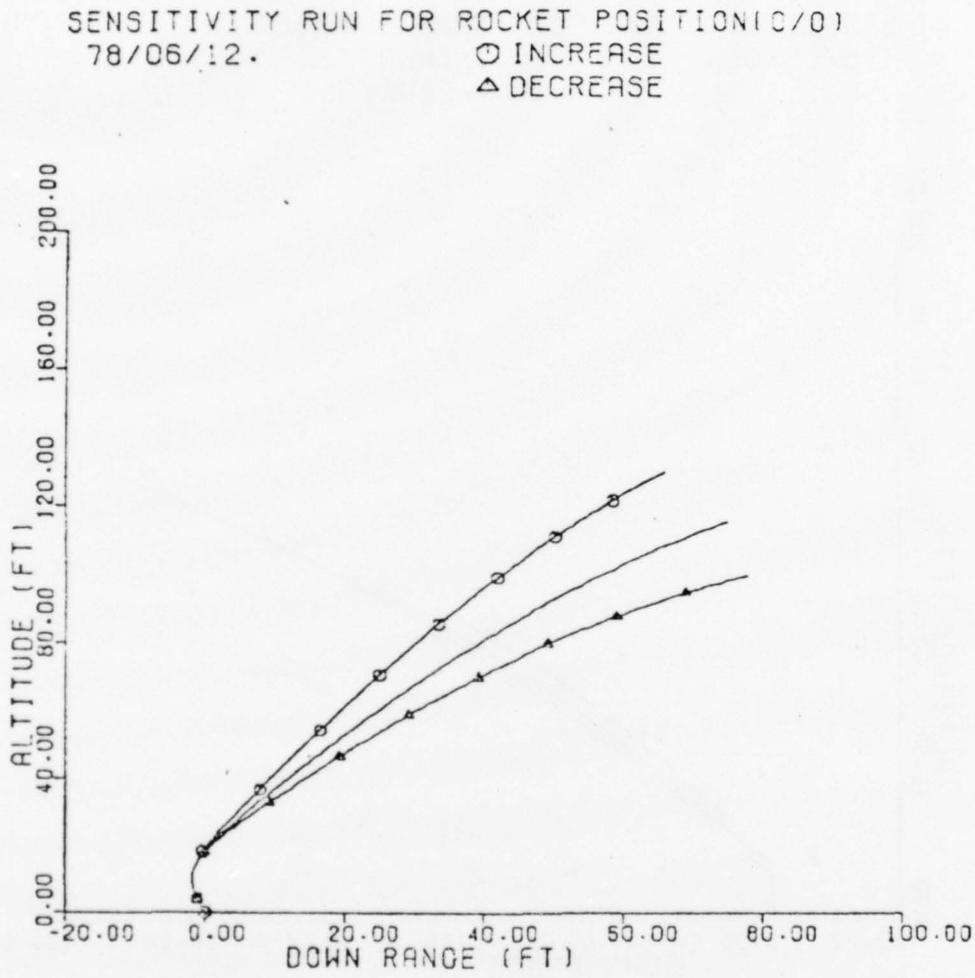

SENSITIVITY RUN FOR ROCKET POSITION(C/O)
78/06/12.
O INCREASE
△ DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-8

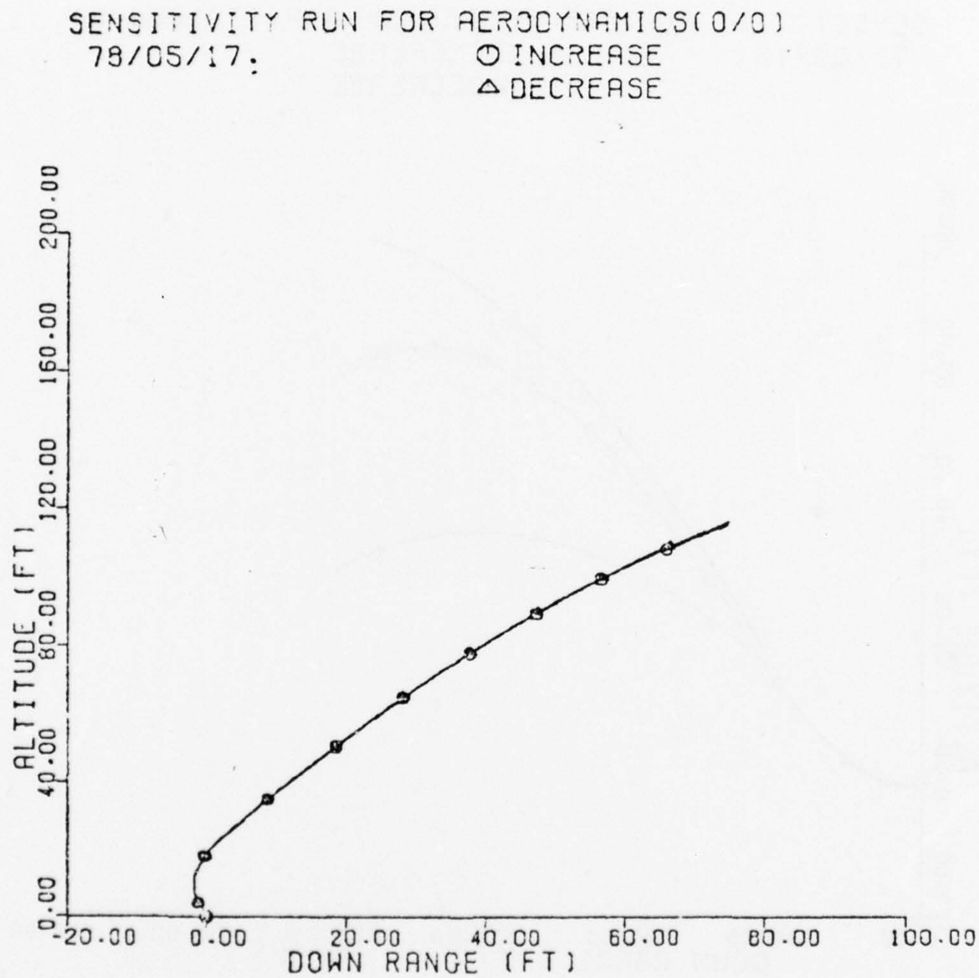

SENSITIVITY RUN FOR AERODYNAMICS(0/0)
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
DOWN RANGE (FT)

Figure A-9

SENSITIVITY RUN FOR CENTER OF GRAVITY(600/0)
78/05/16.
○ INCREASE
△ DECREASE

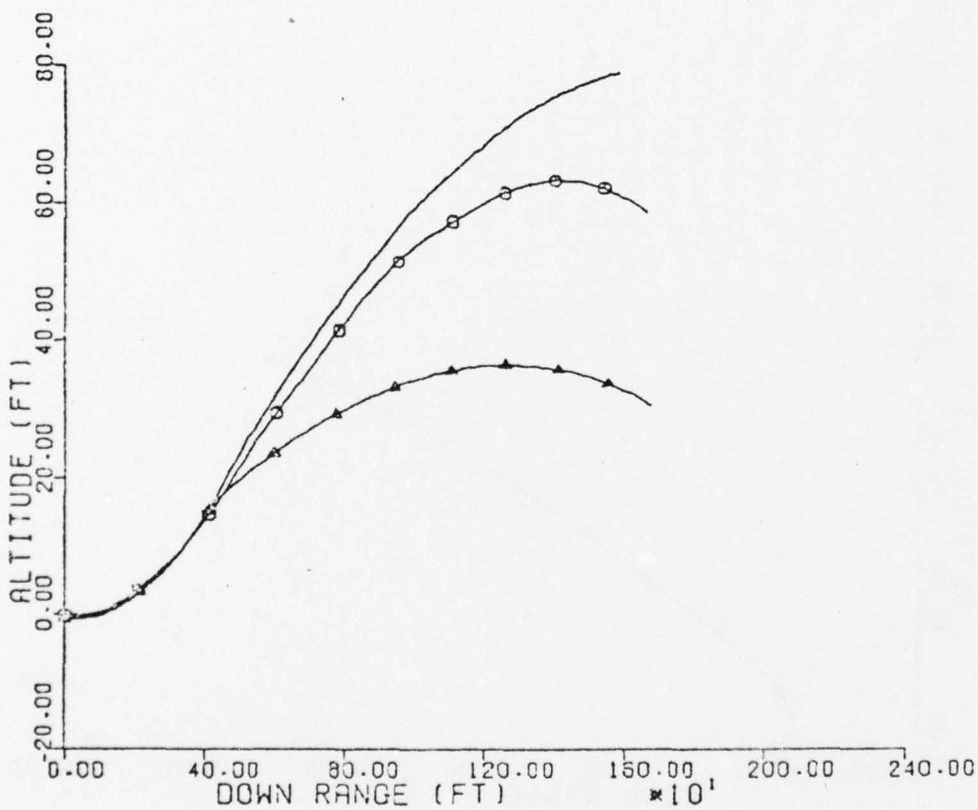


Figure A-10

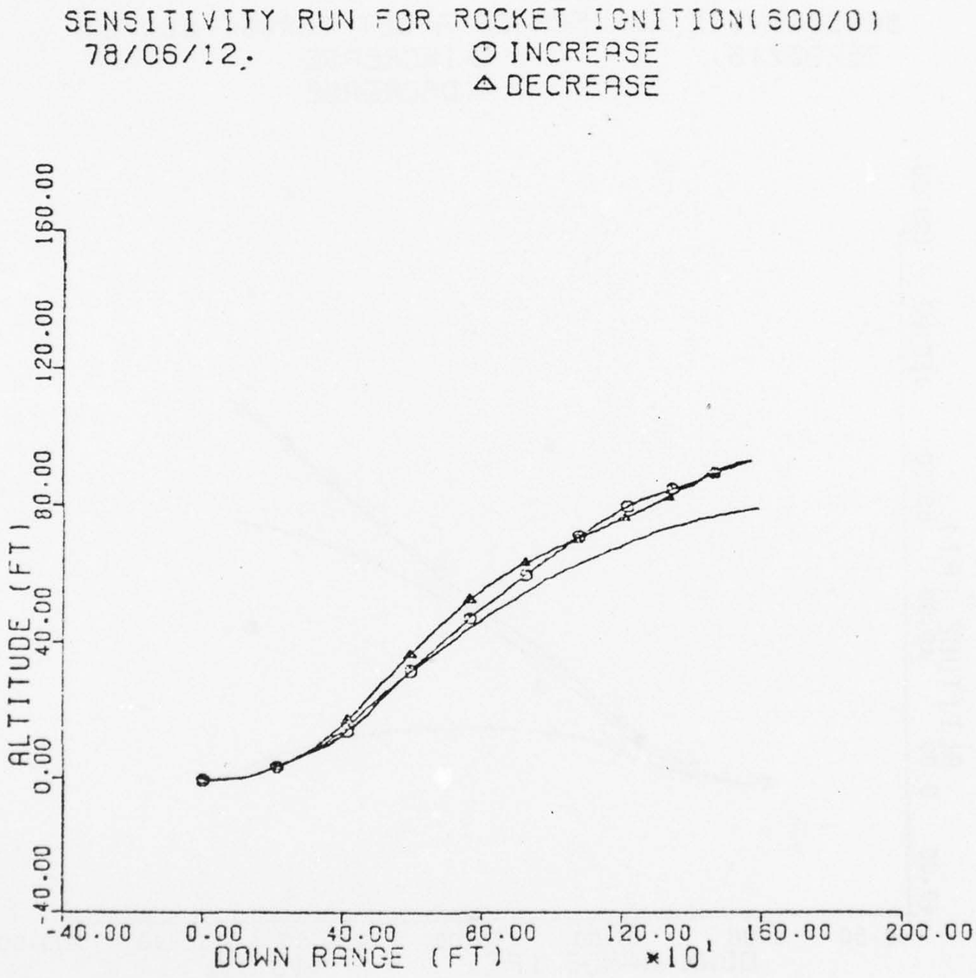

SENSITIVITY RUN FOR ROCKET IGNITION(600/0)
78/06/12.
INCREASE
DECREASE
ALTITUDE (FT)
160.00
120.00
80.00
40.00
0.00
-40.00
-40.00
0.00
40.00
80.00
120.00
160.00
200.00
DOWN RANGE (FT)
*10¹

Figure A-11

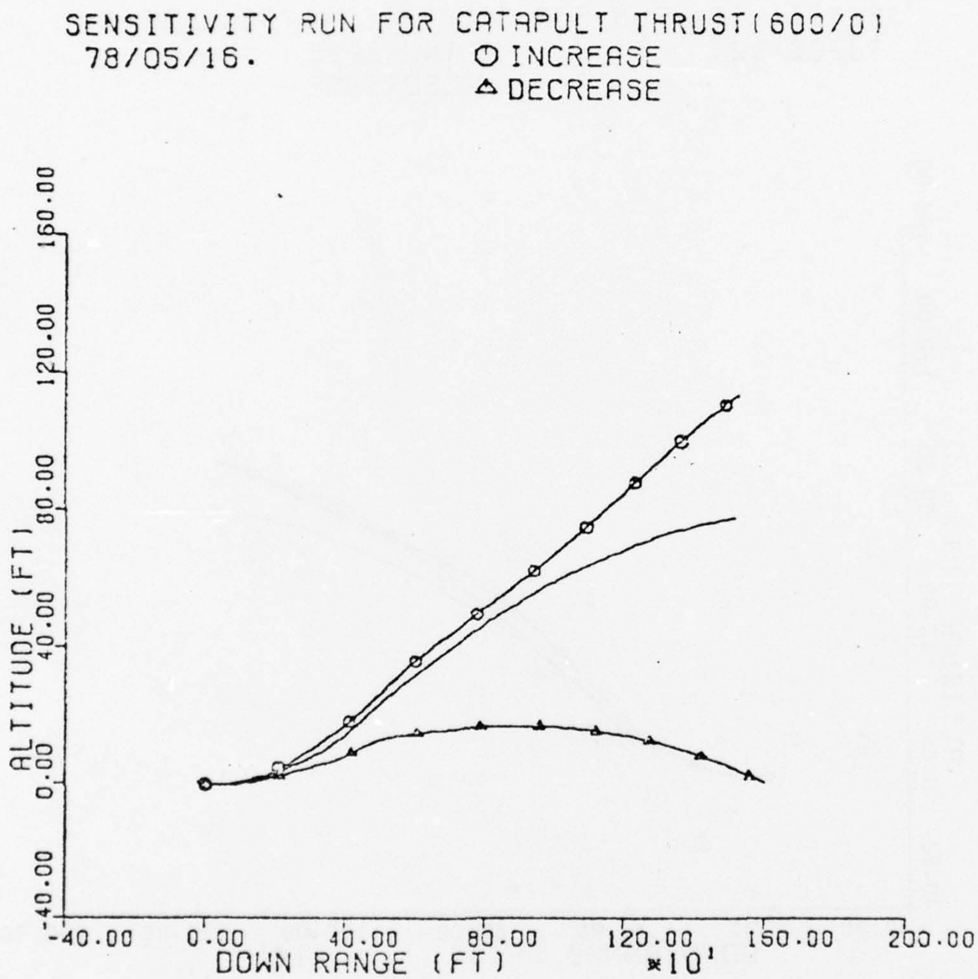

SENSITIVITY RUN FOR CATAPULT THRUST(600/0)
78/05/16.
O INCREASE
△ DECREASE
ALTITUDE (FT)
160.00
120.00
80.00
40.00
0.00
-40.00
-40.00
0.00
40.00
80.00
120.00
160.00
200.00
DOWN RANGE (FT)
*10[1]

Figure A-12

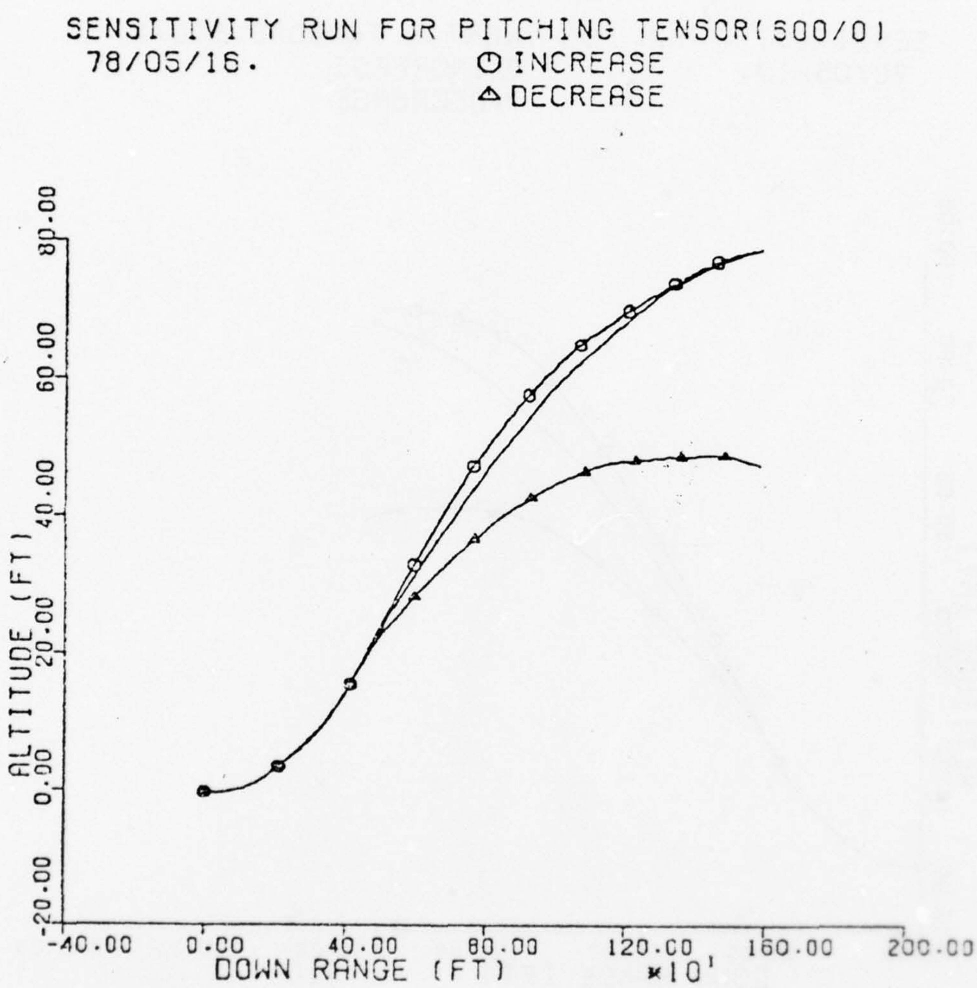

SENSITIVITY RUN FOR PITCHING TENSOR(600/0)
78/05/16.
INCREASE
DECREASE
ALTITUDE (FT)
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
0.00
40.00
80.00
120.00
160.00
200.00
DOWN RANGE (FT)
*10¹

Figure A-13

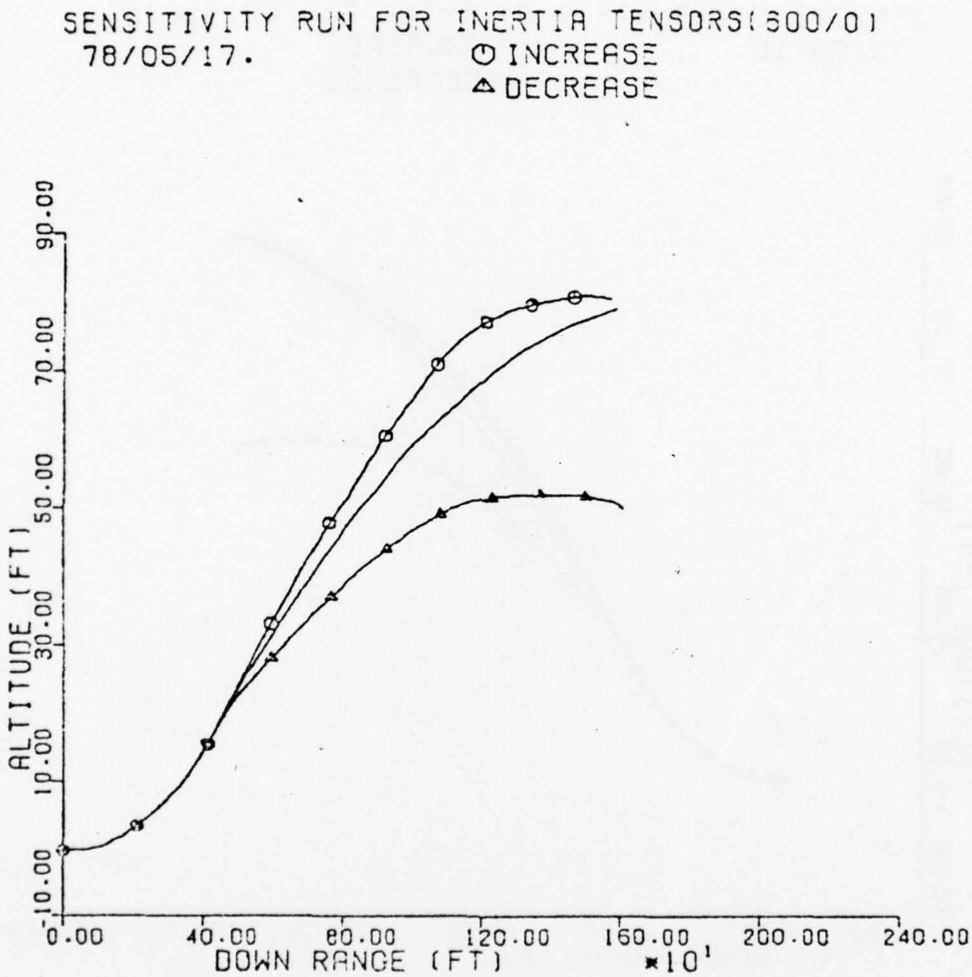

SENSITIVITY RUN FOR INERTIA TENSORS(600/0)
78/05/17.
O INCREASE
△ DECREASE
ALTITUDE (FT)
-10.00
10.00
30.00
50.00
70.00
90.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT)
*10[1]

Figure A-14

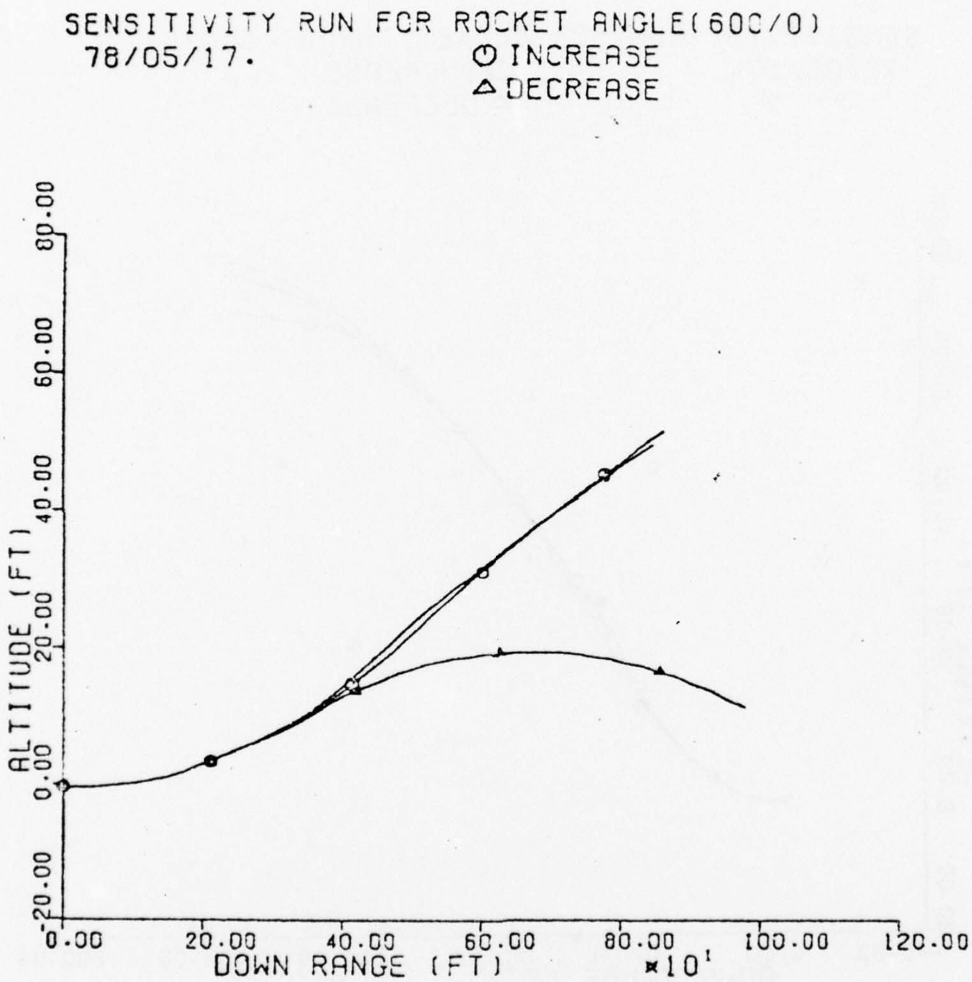

SENSITIVITY RUN FOR ROCKET ANGLE(600/0)
78/05/17.
O INCREASE
△ DECREASE
ALTITUDE (FT)
-20.00
0.00
20.00
40.00
60.00
80.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
DOWN RANGE (FT)
×10¹

Figure A-15

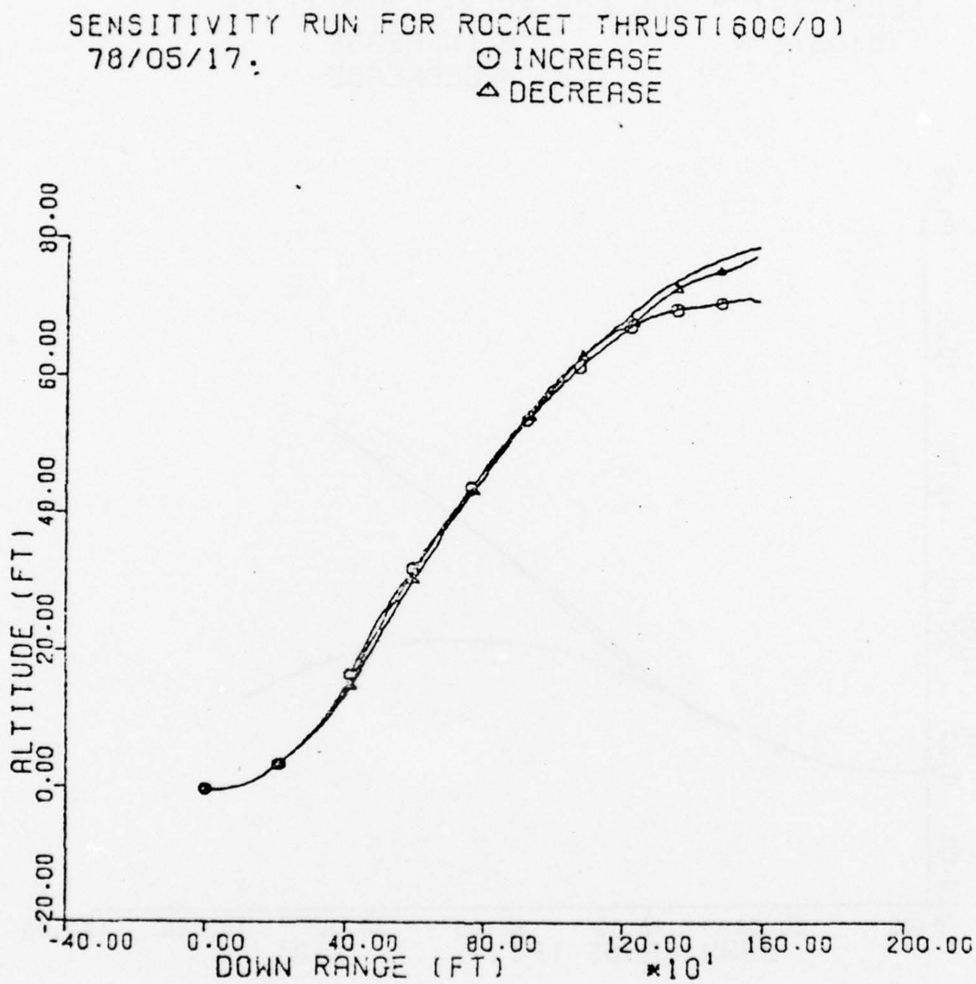

SENSITIVITY RUN FOR ROCKET THRUST(600/0)
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
0.00
40.00
80.00
120.00
160.00
200.00
DOWN RANGE (FT)
*10[1]

Figure A-16

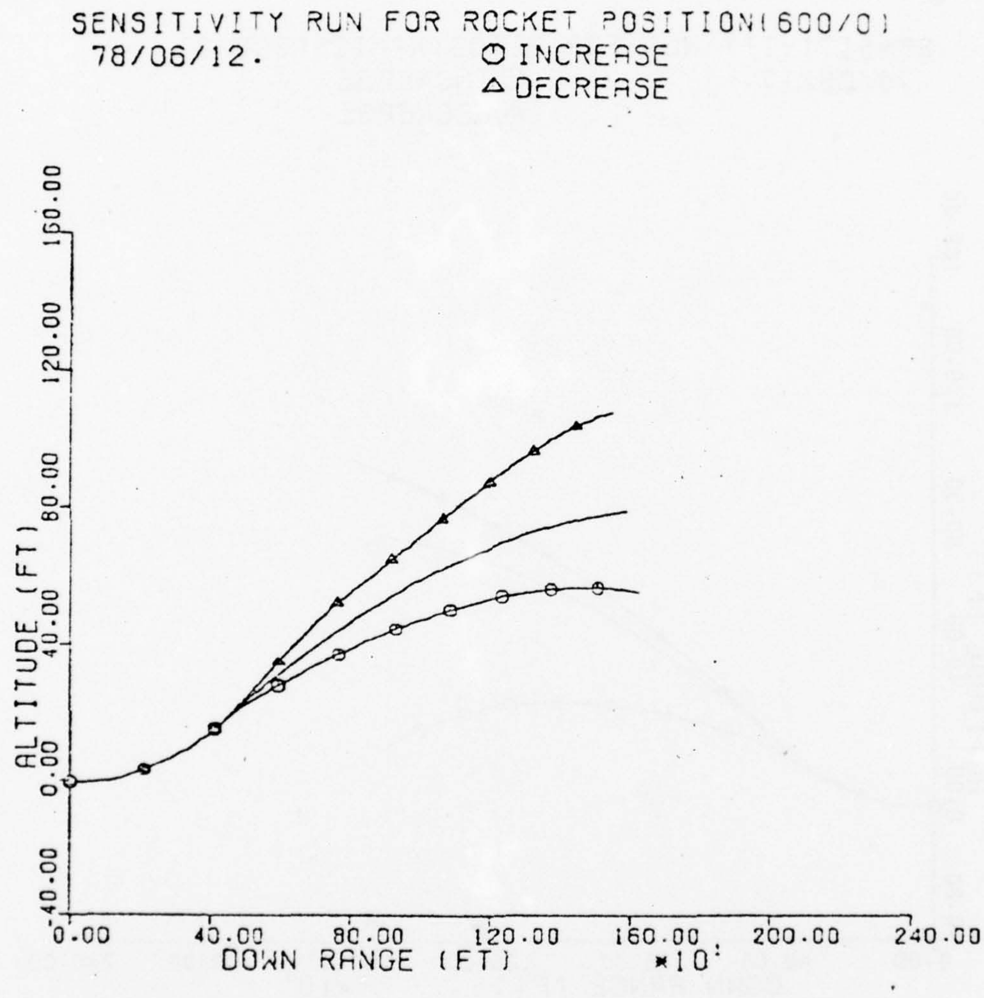
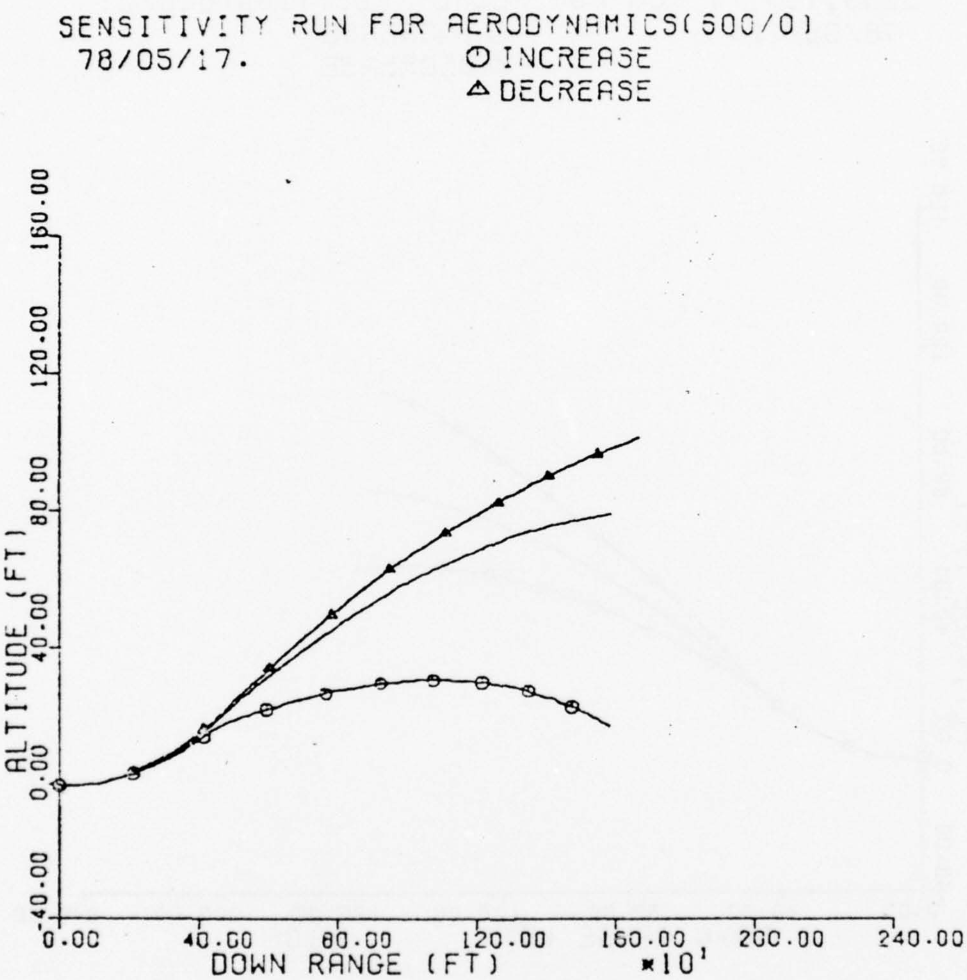

SENSITIVITY RUN FOR ROCKET POSITION(600/0)
78/06/12.
INCREASE
DECREASE
ALTITUDE (FT)
-40.00
0.00
40.00
80.00
120.00
160.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT)
*10

Figure A-17



SENSITIVITY RUN FOR AERODYNAMICS(600/0)
78/05/17.
O INCREASE
△ DECREASE
ALTITUDE (FT)
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT)
*10¹

Figure A-18

DECREASE ROCKET WITH VARIATION IN CATAPULT(600/C)
78/05/17.

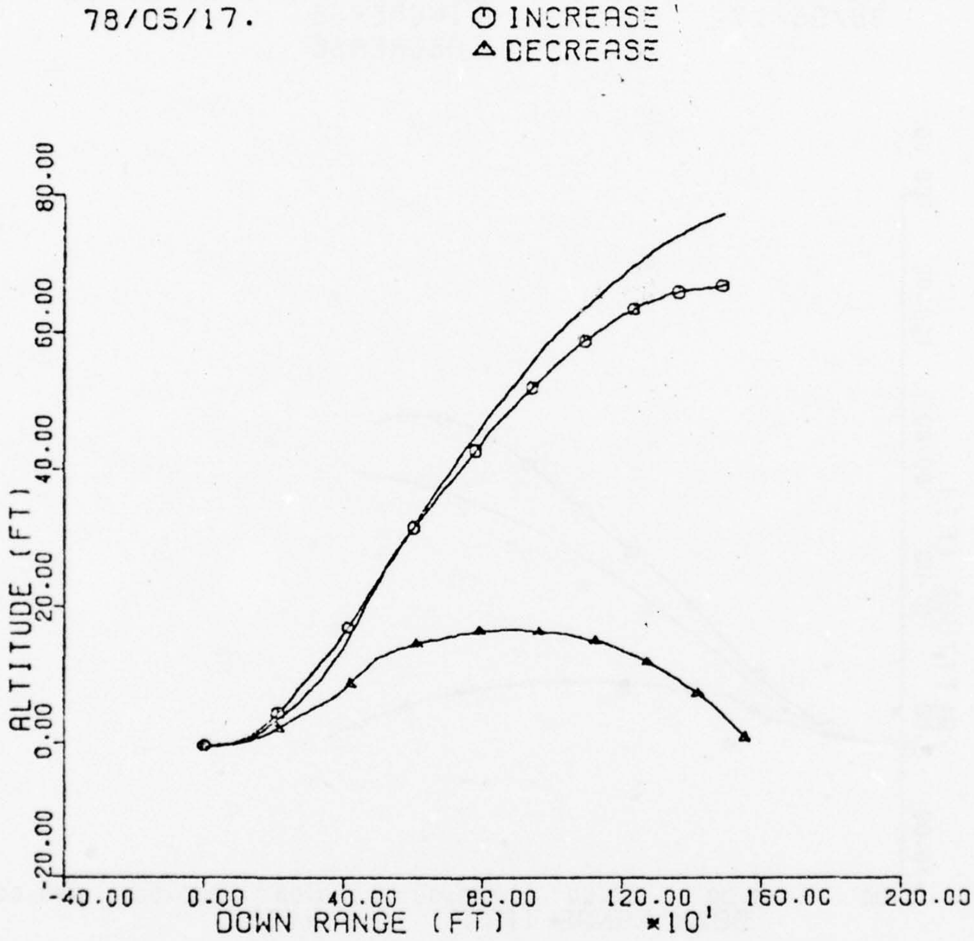


Figure A-19

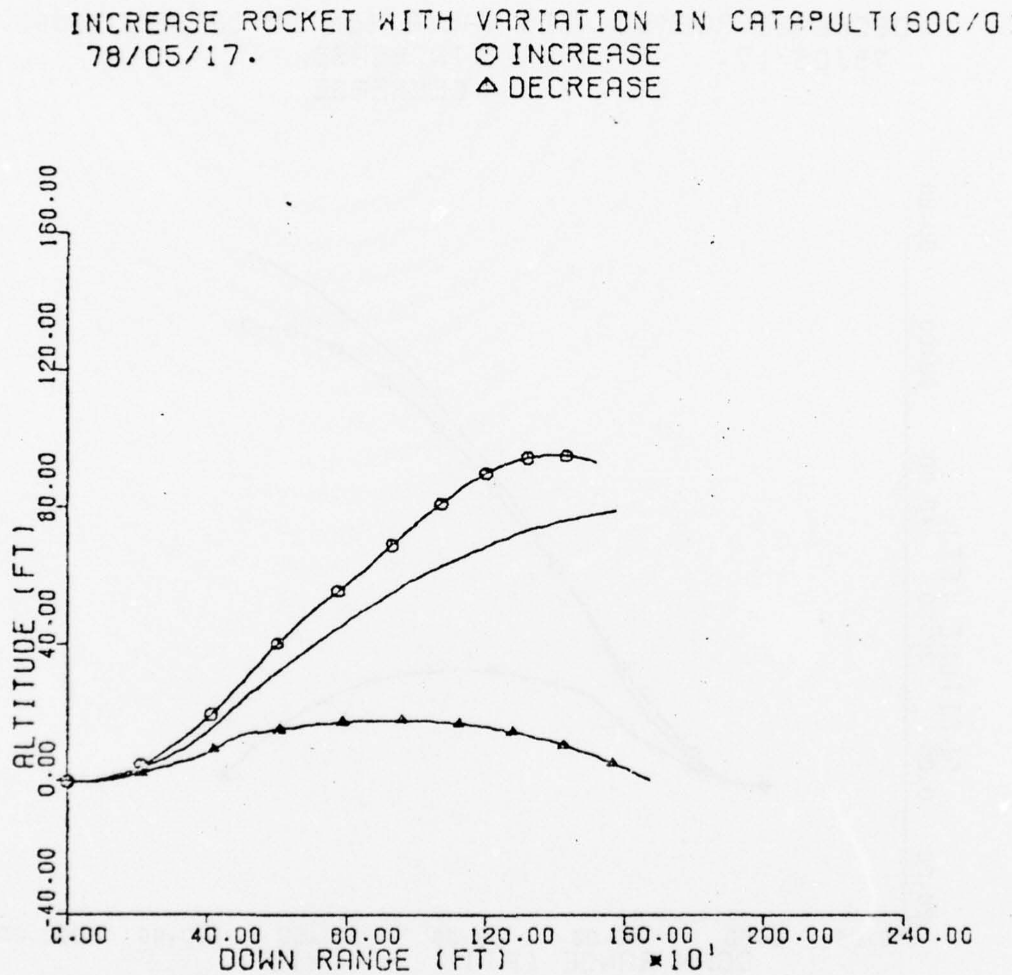
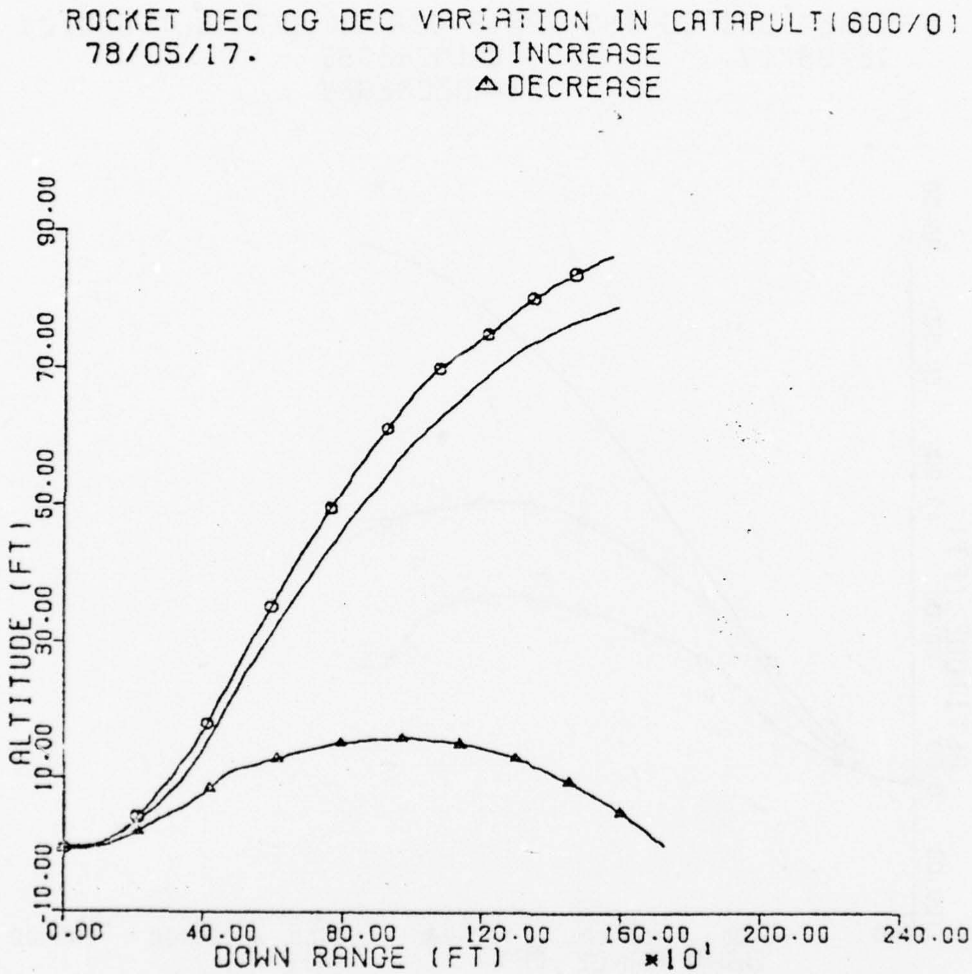

INCREASE ROCKET WITH VARIATION IN CATAPULT(60C/0)
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
DOWN RANGE (FT)
*10¹
-40.00
0.00
40.00
80.00
120.00
160.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00

Figure A-20



ROCKET DEC CG DEC VARIATION IN CATAPULT(600/0)
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
-10.00
10.00
30.00
50.00
70.00
90.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT)
*10¹

Figure A-21

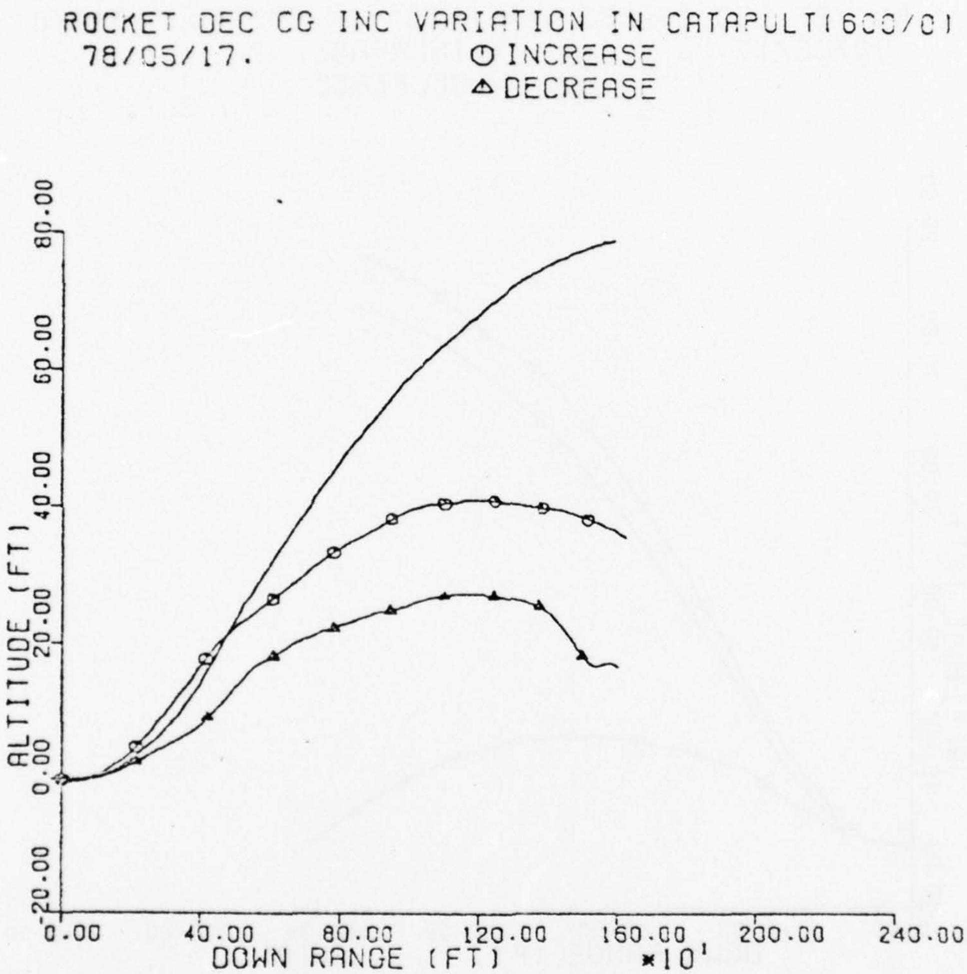

ROCKET DEC CG INC VARIATION IN CATAPULT(600/0)
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
-20.00
0.00
20.00
40.00
60.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT)
*10¹

Figure A-22

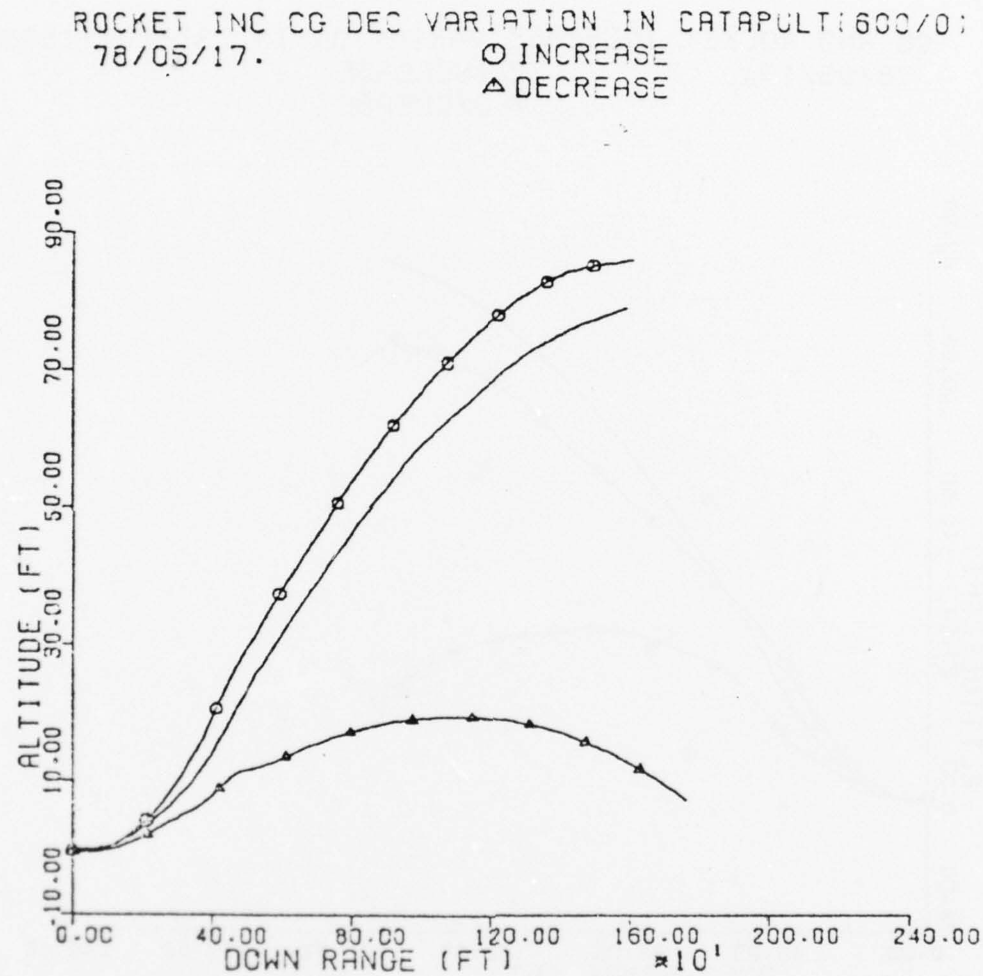

ROCKET INC CG DEC VARIATION IN CATAPULT(600/0)
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
-10.00
10.00
30.00
50.00
70.00
90.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT)
*10[1]

Figure A-23

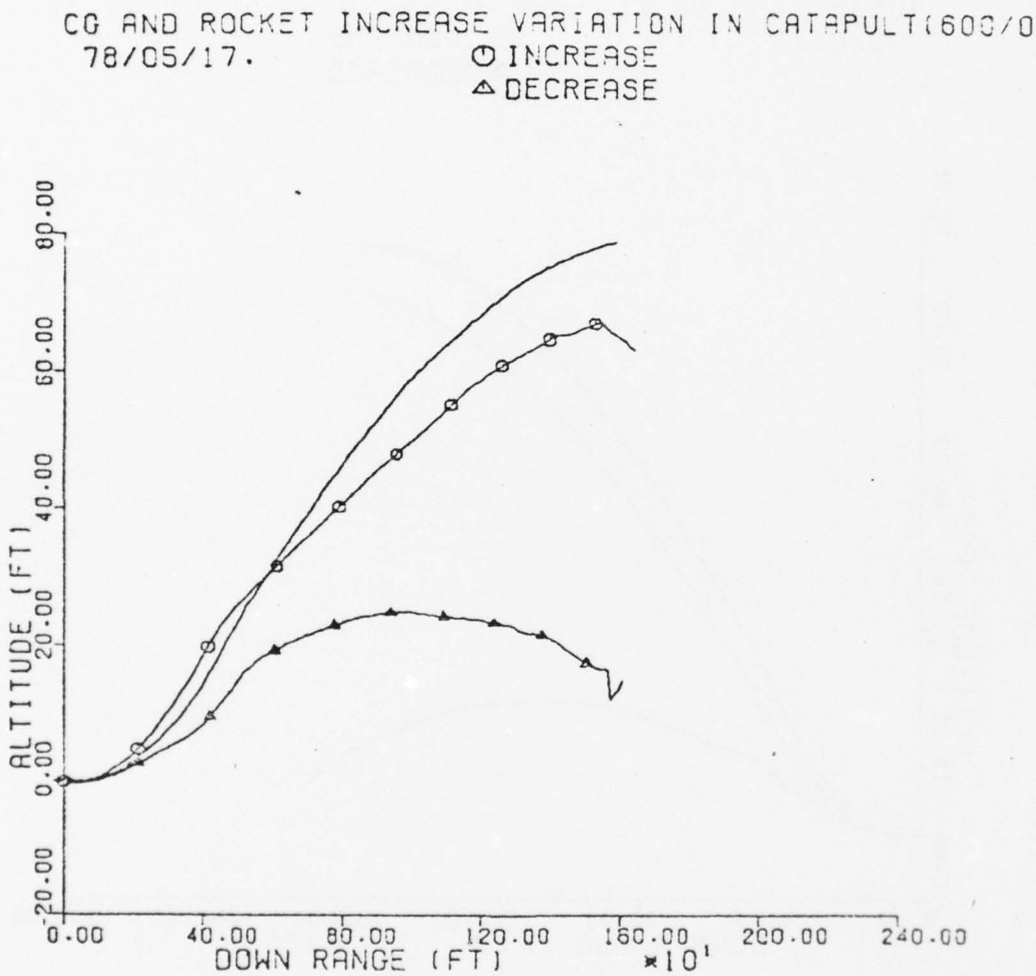

CG AND ROCKET INCREASE VARIATION IN CATAPULT(600/0
78/05/17.
INCREASE
DECREASE
ALTITUDE (FT)
-20.00
0.00
20.00
40.00
60.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
DOWN RANGE (FT) *10[1]

Figure A-24

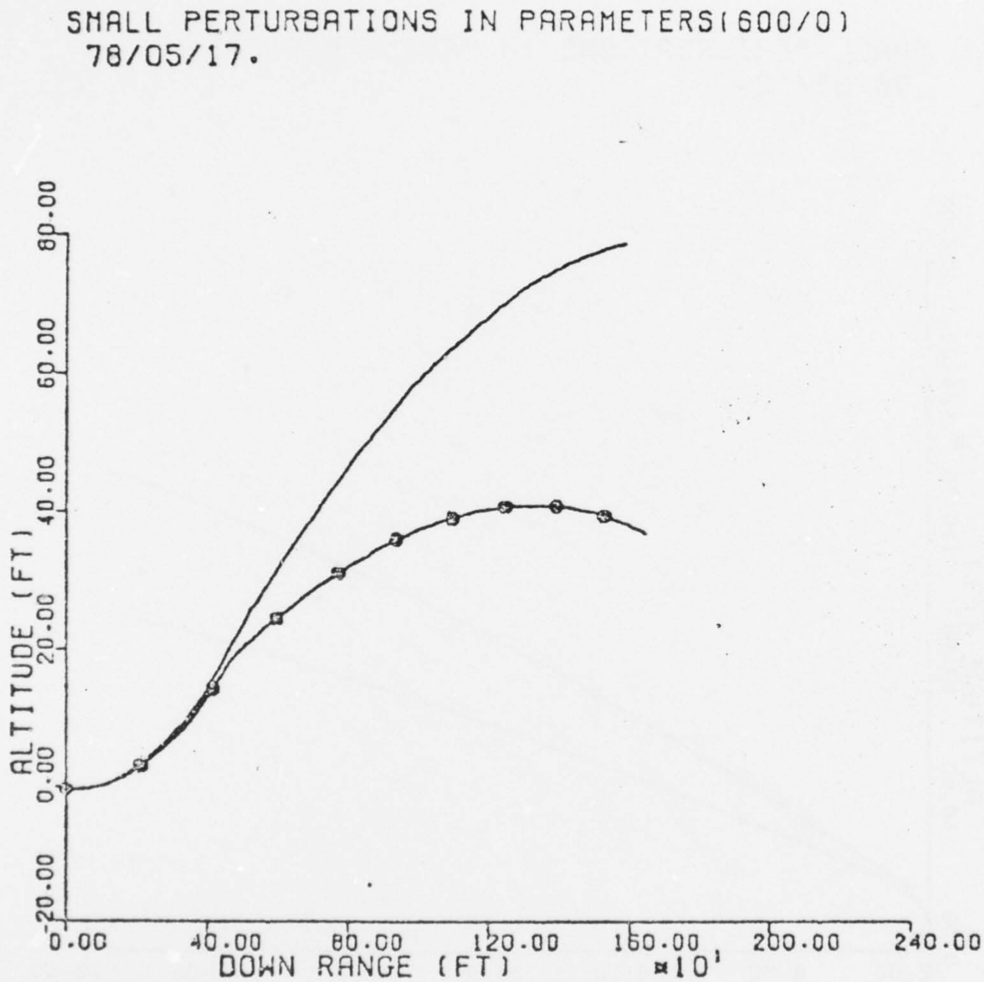

SMALL PERTURBATIONS IN PARAMETERS(600/0)
78/05/17.
ALTITUDE (FT)
-20.00
0.00
20.00
40.00
60.00
80.00
DOWN RANGE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
240.00
×10¹

Figure A-25

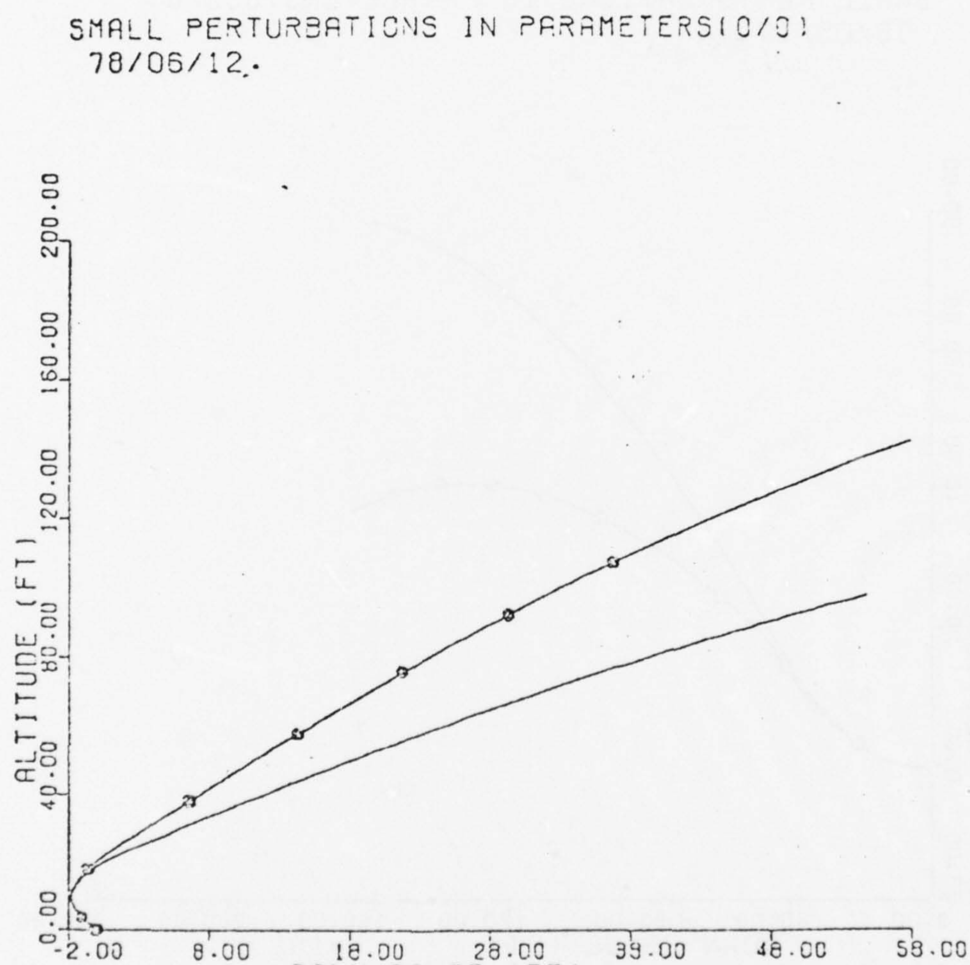

SMALL PERTURBATIONS IN PARAMETERS(0/0)
78/06/12.
ALTITUDE (FT)
0.00
40.00
80.00
120.00
160.00
200.00
-2.00
8.00
18.00
28.00
38.00
48.00
58.00
DOWN RANGE (FT)

Figure A-26

APPENDIX B

TABULATION OF THE $\overline{R} + \sigma$ VALUES

ICARUS $\overline{RES}_x + \sigma_x^{95}$ σ-KNOTS CASE 1

	PHASE			
+20 % Variation	Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
Seat/Man Center Gravity	.22	.77	1.23	2.86
Catapult Thrust	.21	1.40	1.77	3.11
Rocket Thrust	0.00	1.07	2.32	6.77
Rocket Angle	0.00	.62	1.46	5.28
Rocket Ignition	0.00	.61	.59	1.51
Rocket Position	0.00	.29	.80	3.09
Moments of Inertia	.01	.31	.54	1.38
Aero Dynamic Coeffs.	0.00	0.00	0.00	.02
-20 % Variation				
Seat/Man Center Gravity	.18	1.90	3.70	10.76
Catapult Thrust	.24	2.14	4.08	11.02
Rocket Thrust	0.00	1.10	2.41	7.13
Rocket Angle	0.00	1.22	4.12	17.82
Rocket Ignition	.01	.28	.31	2.38
Rocket Position	0.00	.20	.42	1.11
Moments of Inertia	.01	.36	.59	1.42
Aero Dynamic Coeffs.	0.00	0.00	0.00	.02

ICARUS σ-KNOTS CASE 1

$\overline{RES}_Y + \sigma_Y^{95}$

	PHASE			
	Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
+20 % Variation				
Seat/Man Center Gravity	1.15	.28	.74	3.50
Catapult Thrust	0.00	2.32	2.03	1.78
Rocket Thrust	0.00	1.16	2.27	6.32
Rocket Angle	0.00	.62	3.26	12.78
Rocket Ignition	0.00	1.36	2.08	4.94
Rocket Position	0.00	.48	1.55	5.77
Moments of Inertia	0.00	.27	.70	2.25
Aero Dynamic Coeffs.	0.00	.01	.01	.09
-20 % Variation				
Seat/Man Center Gravity	.45	.70	3.00	11.47
Catapult Thrust	1.12	3.73	3.28	3.45
Rocket Thrust	0.00	1.13	2.14	5.83
Rocket Angle	0.00	4.39	7.44	16.07
Rocket Ignition	0.00	1.15	1.46	2.84
Rocket Position	0.00	.51	1.65	6.13
Moments of Inertia	0.00	.34	.87	2.76
Aero Dynamic Coeffs.	0.00	.0o	.01	.10

ICARUS σ-KNOTS CASE 1

$\overline{RES}_z + \sigma_z^{95}$

20 % Variation	PHASE Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
Seat/Man Center Gravity	0.00	.02	.05	.20
Catapult Thrust	0.00	.12	.12	.12
Rocket Thrust	0.00	.19	.61	2.22
Rocket Angle	0.00	.08	.35	1.62
Rocket Ignition	0.00	.13	.16	.16
Rocket Position	0.00	.01	.04	.21
Moments of Inertia	0.00	.07	.21	.76
Aero Dynamic Coeffs.	0.00	0.00	0.00	.01
-20 % Variation				
Seat/Man Center Gravity	0.00	.02	.03	.25
Catapult Thrust	0.00	.17	.20	.19
Rocket Thrust	0.00	.15	.49	1.79
Rocket Angle	0.00	.20	.95	3.75
Rocket Ignition	0.00	.14	.15	.15
Rocket Position	0.00	.01	.06	.31
Moments of Inertia	0.00	.10	.31	1.11
Aero Dynamic Coeffs.	0.00	0.00	0.00	.01

ICARUS $\overline{RES}_p + \sigma_p^{95}$ σ-KNOTS CASE 1

	PHASE			
+20 % Variation	Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	0.00	.45	1.10	1.32
Catapult Thrust	.09	.61	1.23	1.56
Rocket Thrust	0.00	.45	.57	.64
Rocket Angle	0.00	2.22	2.91	3.70
Rocket Ignition	0.00	.21	.26	.27
Rocket Position	0.00	.75	1.88	5.11
Moments of Inertia	0.00	.19	.17	.48
Aero Dynamic Coeffs.	0.00	0.00	0.00	.05
-20 % Variation				
Seat/Man Center Gravity	0.00	1.00	2.44	4.97
Catapult Thrust	0.00	.58	1.88	4.51
Rocket Thrust	0.00	.39	.40	.50
Rocket Angle	0.00	2.50	2.46	4.11
Rocket Ignition	.10	.26	.44	.56
Rocket Position	0.00	.84	2.05	3.71
Moments of Inertia	0.00	.28	.26	.69
Aero Dynamic Coeffs.	0.00	0.00	0.00	.05

ICARUS 95 σ-KNOTS CASE 1

$\overline{RES}_q + \sigma_q$

+20 % Variation	PHASE: Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	.42	1.99	1.92	1.86
Catapult Thrust	3.06	1.32	1.41	1.36
Rocket Thrust	0.00	.73	.71	.71
Rocket Angle	0.00	14.35	13.93	13.74
Rocket Ignition	0.00	.22	.14	.11
Rocket Position	0.00	3.80	3.71	3.77
Moments of Inertia	.35	.56	.03	.10
Aero Dynamic Coeffs.	0.00	0.00	.02	.04
-20 % Variation				
Seat/Man Center Gravity	1.17	4.86	4.91	5.02
Catapult Thrust	2.92	3.06	2.87	2.83
Rocket Thrust	0.00	.66	.64	.62
Rocket Angle	0.00	63.29	61.69	61.04
Rocket Ignition	.15	.24	.34	.33
Rocket Position	0.00	3.80	3.72	3.60
Moments of Inertia	.44	.74	.08	.06
Aero Dynamic Coeffs.	0.00	0.00	.02	.04

ICARUS — σ-KNOTS — CASE 1

$\overline{RES}_r + \sigma_r^{95}$

	PHASE			
+20 % Variation	Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	0.00	.10	.12	3.24
Catapult Thrust	.06	.36	.22	2.90
Rocket Thrust	0.00	.44	.43	1.49
Rocket Angle	0.00	.61	4.67	5.01
Rocket Ignition	0.00	.26	.18	.33
Rocket Position	0.00	.48	1.14	1.37
Moments of Inertia	0.00	.45	.47	.54
Aero Dynamic Coeffs.	0.00	0.00	0.00	0.04
-20 % Variation				
Seat/Man Center Gravity	0.00	.78	1.85	2.71
Catapult Thrust	0.00	.77	.93	1.31
Rocket Thrust	0.00	.47	.53	1.26
Rocket Angle	0.00	3.16	4.41	4.70
Rocket Ignition	.07	.27	.12	.81
Rocket Position	0.00	.20	.55	5.05
Moments of Inertia	0.00	.67	.70	.70
Aero Dynamic Coeffs.	0.00	0.00	0.00	.03

ICARUS $\overline{RES}_x + \sigma_x^{95}$ σ-KNOTS CASE 2

+20 % Variation	PHASE			
	Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
Seat/Man Center Gravity	.16	2.27	4.18	8.82
Catapult Thrust	.32	1.25	2.48	5.26
Rocket Thrust	0.00	.44	.95	2.06
Rocket Angle	0.00	.82	1.94	3.16
Rocket Ignition	0.00	.30	1.19	3.80
Rocket Position	0.00	1.51	4.51	12.90
Moments of Inertia	.01	.45	.81	1.26
Aero Dynamic Coeffs.	0.00	0.00	.01	.03
-20 % Variation				
Seat/Man Center Gravity	.16	3.19	7.66	20.21
Catapult Thrust	.36	2.06	5.18	13.39
Rocket Thrust	0.00	.51	1.19	2.63
Rocket Angle	0.00	.94	5.60	17.24
Rocket Ignition	0.00	.54	1.51	4.19
Rocket Position	.01	1.11	2.65	6.29
Moments of Inertia	0.00	.52	.72	.81
Aero Dynamic Coeffs.	0.00	0.00	.01	.03

ICARUS $\quad \overline{RES}_Y + \sigma_Y^{95}$ σ-KNOTS $\quad$ CASE 2

+20 % Variation	Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
	PHASE			
Seat/Man Center Gravity	.28	1.30	4.93	13.07
Catapult Thrust	1.08	2.93	2.71	2.04
Rocket Thrust	0.00	1.67	2.74	5.92
Rocket Angle	0.00	1.96	6.75	17.92
Rocket Ignition	0.00	1.58	2.01	3.61
Rocket Position	0.00	.50	1.56	4.36
Moments of Inertia	0.00	.30	1.07	3.18
Aero Dynamic Coeffs.	0.00	.02	.05	.26
-20 % Variation				
Seat/Man Center Gravity	.28	.47	2.26	7.13
Catapult Thrust	1.08	5.28	4.60	4.31
Rocket Thrust	0.00	1.72	3.06	6.70
Rocket Angle	0.00	.35	1.48	5.32
Rocket Ignition	.01	1.47	1.68	2.71
Rocket Position	0.00	.99	3.42	9.03
Moments of Inertia	0.00	.46	1.57	4.21
Aero Dynamic Coeffs.	0.00	.02	.05	.26

ICARUS σ-KNOTS CASE 2

$\overline{RES}_z + \sigma_z^{95}$

+20 % Variation	Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
	PHASE			
Seat/Man Center Gravity	0.00	.22	1.06	4.53
Catapult Thrust	0.00	.39	.37	.96
Rocket Thrust	0.00	.81	2.29	5.90
Rocket Angle	0.00	.49	2.45	7.99
Rocket Ignition	0.00	.50	.55	.55
Rocket Position	0.00	.44	1.32	.03
Moments of Inertia	0.00	.29	.78	1.76
Aero Dynamic Coeffs.	0.00	0.00	.01	3.13
-20 % Variation				
Seat/Man Center Gravity	0.00	.07	.35	1.09
Catapult Thrust	0.00	.62	.65	.79
Rocket Thrust	0.00	.68	2.01	5.34
Rocket Angle	0.00	.17	.14	1.66
Rocket Ignition	0.00	.50	.54	.52
Rocket Position	0.00	.52	1.01	2.03
Moments of Inertia	0.00	.40	.01	.03
Aero Dynamic Coeffs.	0.00	0.00	1.78	6.20

ICARUS σ-KNOTS CASE 2

$\overline{RES}_p + \sigma_p^{95}$

	PHASE			
+20 % Variation	Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	0.00	3.05	10.14	17.23
Catapult Thrust	.14	1.16	3.49	5.26
Rocket Thrust	0.00	1.96	1.86	2.77
Rocket Angle	0.00	5.77	14.95	30.07
Rocket Ignition	0.00	.86	.53	.80
Rocket Position	0.00	3.04	5.75	17.07
Moments of Inertia	0.00	1.51	1.35	3.30
Aero Dynamic Coeffs.	0.00	.02	.04	.07
-20 % Variation				
Seat/Man Center Gravity	0.00	1.24	3.98	13.61
Catapult Thrust	0.00	1.32	3.48	10.27
Rocket Thrust	0.00	1.96	1.84	1.49
Rocket Angle	0.00	5.54	11.22	25.30
Rocket Ignition	.19	.86	.64	.99
Rocket Position	0.00	3.71	8.07	12.92
Moments of Inertia	0.00	2.17	1.97	5.48
Aero Dynamic Coeffs.	0.00	.02	.06	.06

ICARUS

$\overline{RES}_q + \sigma_q^{95}$ σ-KNOTS

CASE 2

	PHASE			
+20 % Variation	Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	.81	9.45	9.27	10.59
Catapult Thrust	3.21	2.21	2.32	1.73
Rocket Thrust	0.00	.20	1.19	1.84
Rocket Angle	0.00	19.54	19.70	21.40
Rocket Ignition	0.00	.17	.26	.34
Rocket Position	0.00	8.95	11.82	16.25
Moments of Inertia	.34	.69	1.44	2.31
Aero Dynamic Coeffs.	0.00	.03	.04	.07
-20 % Variation				
Seat/Man Center Gravity	.87	9.86	12.80	17.10
Catapult Thrust	2.96	3.46	4.56	5.92
Rocket Thrust	0.00	.14	.96	1.65
Rocket Angle	0.00	17.39	14.68	18.82
Rocket Ignition	.01	.29	.34	.39
Rocket Position	0.00	8.43	7.94	8185
Moments of Inertia	.48	1.08	2.45	2.95
Aero Dynamic Coeffs.	0.00	.03	.04	.07

ICARUS

CASE 2

$\overline{RES}_r + \sigma_r^{95}$ σ-KNOTS

+20 % Variation	PHASE Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	0.00	2.11	2.49	11.25
Catapult Thrust	.01	1.24	1.43	3.14
Rocket Thrust	0.00	.46	1.24	1.76
Rocket Angle	0.00	4.67	5.77	19.16
Rocket Ignition	0.00	.32	.27	.308
Rocket Position	0.00	2.61	7.60	10.51
Moments of Inertia	0.00	.61	1.35	2.07
Aero Dynamic Coeffs.	0.00	.05	.06	.03
-20 % Variation				
Seat/Man Center Gravity	0.00	2.86	7.70	11.42
Catapult Thrust	0.00	1.51	3.29	5.41
Rocket Thrust	0.00	.47	1.12	1.77
Rocket Angle	0.00	5.42	5.02	11.41
Rocket Ignition	.01	.34	.32	.40
Rocket Position	0.00	.99	.05	8.06
Moments of Inertia	0.00	1.04	2.25	3.21
Aero Dynamic Coeffs.	0.00	.05	1.15	.03

ICARUS 600-KNOTS CASE 1

$\overline{RES}_x + \sigma_x^{95}$

	PHASE			
+20 % Variation	Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
Seat/Man Center Gravity	.11	3.49	12.80	32.79
Catapult Thrust	.54	2.65	7.77	19.38
Rocket Thrust	0.00	1.25	1.73	2.58
Rocket Angle	0.00	.80	5.78	20.56
Rocket Ignition	0.00	1.59	2.77	2.16
Rocket Position	0.00	.46	1.16	7.55
Moments of Inertia	0.00	.56	1.44	1.32
Aero Dynamic Coeffs.	.05	.46	1.57	2.24
-20 % Variation				
Seat/Man Center Gravity	.11	.87	5.28	23.52
Catapult Thrust	.57	7.87	14.31	37.45
Rocket Thrust	0.00	1.27	2.08	4.82
Rocket Angle	0.00	10.54	31.56	130.80
Rocket Ignition	.01	1.21	1.01	1.43
Rocket Position	0.00	.94	1.30	3.99
Moments of Inertia	0.00	.63	1.48	7.44
Aero Dynamic Coeffs.	.05	4.52	10.72	28.62

ICARUS 600-KNOTS CASE 1

$\overline{RES}_y + \sigma_y^{95}$

	PHASE			
+20 % Variation	Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
Seat/Man Center Gravity	.28	1.86	1.81	2.76
Catapult Thrust	1.40	2.80	4.92	7.38
Rocket Thrust	0.00	1.27	.95	.90
Rocket Angle	0.00	1.70	1.42	2.98
Rocket Ignition	0.00	2.11	1.34	5.13
Rocket Position	0.00	.95	3.22	9.99
Moments of Inertia	0.00	.37	2.03	6.08
Aero Dynamic Coeffs.	.39	4.38	9.40	25.07
-20 % Variation				
Seat/Man Center Gravity	.28	3.46	7.99	21.56
Catapult Thrust	1.66	10.00	16.79	37.94
Rocket Thrust	0.00	1.46	1.28	1.00
Rocket Angle	0.00	5.80	12.40	37.05
Rocket Ignition	.06	2.76	5.33	8.95
Rocket Position	0.00	.63	4.08	10.9-
Moments of Inertia	0.00	.93	3.23	10.38
Aero Dynamic Coeffs.	.39	1.08	3.04	8.68

ICARUS 600-KNOTS CASE 1

$\overline{RES}_z + \sigma_z^{95}$

+20 % Variation	PHASE Catapult (Ft)	Rocket (Ft)	Rocket to Drogue Projection (Ft)	Drogue Proj. to 1 Sec. (Ft)
Seat/Man Center Gravity	0.00	.52	1.91	8.35
Catapult Thrust	0.00	.60	2.72	14.13
Rocket Thrust	0.00	.31	.70	1.72
Rocket Angle	0.00	.40	.46	.67
Rocket Ignition	0.00	.41	.43	.54
Rocket Position	0.00	.10	.62	3.12
Moments of Inertia	0.00	.13	.20	.64
Aero Dynamic Coeffs.	0.00	.28	1.10	4.45
-20 % Variation				
Seat/Man Center Gravity	0.00	.41	1.82	7.80
Catapult Thrust	0.00	.75	1.88	6.33
Rocket Thrust	0.00	.31	.72	2.08
Rocket Angle	0.00	5.22	13.51	51.60
Rocket Ignition	0.00	.34	.44	1.61
Rocket Position	0.00	.12	.21	.49
Moments of Inertia	0.00	.14	.19	.22
Aero Dynamic Coeffs.	0.00	.16	.84	9.26

ICARUS 600-KNOTS CASE 1

$\overline{RES}_p + \sigma_p^{95}$

+20 % Variation	PHASE: Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	0.00	6.64	10.63	32.82
Catapult Thrust	.24	8.59	5.28	15.73
Rocket Thrust	0.00	1.53	5.03	13.52
Rocket Angle	0.00	3.68	2.46	15.52
Rocket Ignition	0.00	.98	9.44	21.91
Rocket Position	0.00	4.16	10.52	17.70
Moments of Inertia	0.00	.76	4.59	13.51
Aero Dynamic Coeffs.	0.00	5.86	12.77	16.83
-20 % Variation				
Seat/Man Center Gravity	0.00	5.05	9.34	10.72
Catapult Thrust	0.00	1.90	7.80	14.59
Rocket Thrust	0.00	.88	4.05	16.17
Rocket Angle	0.00	32.17	38.69	57.47
Rocket Ignition	.27	1.37	4.83	39.82
Rocket Position	0.00	2.88	13.71	26.55
Moments of Inertia	0.00	4.93	10.61	20.08
Aero Dynamic Coeffs.	.01	3.74	9.21	35.42

ICARUS 600-KNOTS CASE 1

$\overline{RES}_q + \sigma_q^{95}$

+20 % Variation	PHASE Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	.30	44.38	38.59	34.57
Catapult Thrust	3.78	31.55	31.71	32.17
Rocket Thrust	0.00	3.68	3.45	7.75
Rocket Angle	0.00	43.25	42.94	44.42
Rocket Ignition	0.00	9.32	6.21	13.17
Rocket Position	0.00	7.72	7.47	13.37
Moments of Inertia	.40	5.05	4.11	8.45
Aero Dynamic Coeffs.	.73	12.81	6.78	14.64
-20 % Variation				
Seat/Man Center Gravity	.38	17.06	8.58	15.26
Catapult Thrust	2.83	6.79	8.76	14.92
Rocket Thrust	0.00	4.54	3.66	11.01
Rocket Angle	0.00	63.54	62.81	66.23
Rocket Ignition	.07	2.89	4.61	26.04
Rocket Position	0.00	11.05	8.78	12.28
Moments of Inertia	.50	8.08	6.77	11.94
Aero Dynamic Coeffs.	1.17	27.01	31.95	30.59

ICARUS 600-KNOTS CASE 1

$\overline{RES}_r + \sigma_r^{95}$

+20 % Variation	Catapult (Rad/Sec)	Rocket (Rad/Sec)	Rocket to Drogue Projection (Rad/Sec)	Drogue Proj. to 1 Sec. (Rad/Sec)
Seat/Man Center Gravity	0.00	6.72	8.95	18.54
Catapult Thrust	.14	7.90	11.23	37.37
Rocket Thrust	0.00	1.75	5.46	14.36
Rocket Angle	0.00	14.65	21.03	14.92
Rocket Ignition	0.00	2.20	12.49	16.44
Rocket Position	0.00	1.18	8.65	16.28
Moments of Inertia	0.00	2.18	6.36	12.04
Aero Dynamic Coeffs.	0.00	2.99	10.16	16.02
-20 % Variation				
Seat/Man Center Gravity	0.00	6.31	11.42	11.58
Catapult Thrust	0.00	2.52	4.49	14.23
Rocket Thrust	0.00	1.86	5.78	13.39
Rocket Angle	0.00	36.47	42.70	59.67
Rocket Ignition	.16	3.36	4.18	7.43
Rocket Position	0.00	.92	20.90	23.81
Moments of Inertia	0.00	3.37	9.60	19.45
Aero Dynamic Coeffs.	.01	11.34	15.23	23.80

ICARUS 600-KNOTS CASE 2

$\overline{RES}_x + \sigma_x^{95}$

	PHASE			
+20 % Variation	Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
Seat/Man Center Gravity	.12	.41	1.32	1.48
Catapult Thrust	.42	3.93	4.54	8.87
Rocket Thrust	0.00	.93	1.56	3.43
Rocket Angle	0.00	2.44	2.68	2.16
Rocket Ignition	0.00	.86	1.65	3.35
Rocket Position	0.00	.31	.79	2.92
Moments of Inertia	0.00	.13	.15	1.46
Aero Dynamic Coeffs.	.06	2.33	5.63	16.81
-20 % Variation				
Seat/Man Center Gravity	.12	1.03	2.26	5.73
Catapult Thrust	.43	4.99	7.16	16.36
Rocket Thrust	0.00	.95	1.86	5.25
Rocket Angle	0.00	2.20	5.15	14.87
Rocket Ignition	0.00	1.19	1.29	2.16
Rocket Position	0.00	.20	.84	4.31
Moments of Inertia	0.00	.16	.24	.77
Aero Dynamic Coeffs.	.05	2.41	6.59	22.11

ICARUS 600-KNOTS CASE 2

$\overline{RES}_y + \sigma_y^{95}$

+20 % Variation	Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
			PHASE	
Seat/Man Center Gravity	.28	.39	.54	6.85
Catapult Thrust	.99	2.56	2.55	4.75
Rocket Thrust	0.00	1.41	2.14	5.36
Rocket Angle	0.00	1.56	2.78	3.97
Rocket Ignition	0.00	1.62	1.82	2.73
Rocket Position	0.00	.20	.25	5.27
Moments of Inertia	0.00	.05	.58	1.08
Aero Dynamic Coeffs.	.05	.23	.57	4.46
-20 % Variation				
Seat/Man Center Gravity	.27	.45	.86	2.37
Catapult Thrust	.99	3.64	3.32	6.79
Rocket Thrust	0.00	1.52	2.71	6.86
Rocket Angle	0.00	2.09	5.40	18.72
Rocket Ignition	0.00	1.42	1.37	2.19
Rocket Position	0.00	.27	.48	3.22
Moments of Inertia	.01	.13	1.27	1.86
Aero Dynamic Coeffs.	.06	.67	1.56	5.86

ICARUS 600-KNOTS CASE 2

$\overline{RES_z} + \sigma_z^{95}$

	PHASE			
+20 % Variation	Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
Seat/Man Center Gravity	0.00	.51	1.60	3.00
Catapult Thrust	0.00	.21	.25	3.63
Rocket Thrust	0.00	.54	1.99	5.88
Rocket Angle	0.00	.80	4.87	20.87
Rocket Ignition	0.00	.10	.15	.82
Rocket Position	0.00	.15	.73	3.96
Moments of Inertia	0.00	.07	.82	1.78
Aero Dynamic Coeffs.	0.00	.20	.26	3.73
-20 % Variation				
Seat/Man Center Gravity	0.00	.36	.89	2.22
Catapult Thrust	0.00	.04	.10	5.10
Rocket Thrust	0.00	.40	1.82	4.66
Rocket Angle	0.00	1.75	5.28	16.97
Rocket Ignition	0.00	.13	.11	.08
Rocket Position	0.00	.03	.12	4.32
Moments of Inertia	0.00	.15	.90	2.58
Aero Dynamic Coeffs.	0.00	.30	.43	1.00

ICARUS 600-KNOTS CASE 2

$\overline{RES}_p + \sigma_p^{95}$

+20 % Variation	PHASE: Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
Seat/Man Center Gravity	0.00	7.38	9.26	12.05
Catapult Thrust	.04	1.06	1.27	4.93
Rocket Thrust	0.00	2.53	1.50	3.27
Rocket Angle	0.00	5.12	7.33	7.35
Rocket Ignition	0.00	2.62	1.25	.68
Rocket Position	0.00	2.80	3.52	13.72
Moments of Inertia	0.00	3.17	2.66	5.16
Aero Dynamic Coeffs.	0.00	1.54	.70	8.12

-20 % Variation	Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
Seat/Man Center Gravity	0.00	9.95	11.38	18.12
Catapult Thrust	0.00	3.00	3.84	15.13
Rocket Thrust	0.00	2.81	1.96	4.61
Rocket Angle	0.00	4.81	5.87	14.14
Rocket Ignition	.05	2.25	.99	1.89
Rocket Position	0.00	4.67	5.14	13.40
Moments of Inertia	0.00	4.39	2.30	5.80
Aero Dynamic Coeffs.	0.00	2.30	2.53	3.22

ICARUS | 600-KNOTS | CASE 2

$\overline{RES}_q + \sigma_q^{95}$

	PHASE			
+20 % Variation	Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
Seat/Man Center Gravity	.40	4.60	8.54	10.17
Catapult Thrust	.69	1.93	.55	1.76
Rocket Thrust	0.00	.85	1.45	1.05
Rocket Angle	0.00	4.75	2.50	5.06
Rocket Ignition	0.00	.82	1.10	.93
Rocket Position	0.00	2.79	1.58	6.86
Moments of Inertia	.14	.64	2.01	1.75
Aero Dynamic Coeffs.	.74	1.17	.64	4.04
-20 % Variation				
Seat/Man Center Gravity	.44	7.43	11.79	10.42
Catapult Thrust	.77	2.81	3.03	6.91
Rocket Thrust	0.00	.80	1.53	1.33
Rocket Angle	0.00	4.95	13.05	13.67
Rocket Ignition	.04	.88	.99	.66
Rocket Position	0.00	3.06	5.04	5.79
Moments of Inertia	.22	1.53	2.80	2.59
Aero Dynamic Coeffs.	.78	1.26	2.75	2.56

ICARUS 600-KNOTS CASE 2

$\overline{RES}_r + \sigma_r^{95}$

+20 % Variation	Catapult	Rocket	Rocket to Drogue Projection	Drogue Proj. to 1 Sec.
	PHASE			
Seat/Man Center Gravity	0.00	6.81	8.03	9.84
Catapult Thrust	0.00	.72	2.96	6.96
Rocket Thrust	0.00	.54	2.12	7.85
Rocket Angle	0.00	8.51	2.26	9.85
Rocket Ignition	0.00	1.20	1.44	1.72
Rocket Position	0.00	2.53	4.51	16.73
Moments of Inertia	0.00	1.43	1.74	12.04
Aero Dynamic Coeffs.	0.00	.47	2.60	9.42
-20 % Variation				
Seat/Man Center Gravity	0.00	5.49	12.08	23.40
Catapult Thrust	0.00	3.28	4.42	14.27
Rocket Thrust	0.00	.74	1.68	10.05
Rocket Angle	0.00	11.37	13.90	21.47
Rocket Ignition	0.00	1.09	.82	2.66
Rocket Position	0.00	3.55	4.50	14.48
Moments of Inertia	0.00	1.79	3.90	13.90
Aero Dynamic Coeffs.	0.00	2.46	3.06	7.25

APPENDIX C

TABULATION OF THE COEFFICIENTS OF CONCORDANCE, F-VALUES, SPEARMAN'S RANK CORRELATION COEFFICIENTS AND RANKINGS OF THE INPUT PARAMETERS

AD-A062 429 COMPUTER SCIENCES CORP TREVOSE PA F/G 1/3
ESCAPE SYSTEM TRAJECTORY SENSITIVITY ANALYSIS.(U)
AUG 78 J J PIACENTINO, J F MCENERNEY N62269-75-C-0001
UNCLASSIFIED NADC-77100-40 NL

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TABLE 1

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY COMPONENT RANKINGS

CASE 1

Initial Velocity 0-Knots	Trajectory Ranking Component	Coefficient of Concordance (0 to 1)	F-Value* (2.92 @ 95% Level) (2.28 @ 90% Level)	Spearman's Rank Correlation Coeffiient (-1 to +1)
+20% Variation				
	X	.92	20.22	.85
	Y	.75	6.00	.62
	Z	.77	6.70	.66
	P	.97	64.67	.96
	Q	.98	98.00	.97
	R	.74	5.69	.61
-20% Variation				
	X	.93	26.57	.90
	Y	.82	9.11	.88
	Z	.81	8.53	.72
	P	.89	16.18	.84
	Q	.96	48.00	.94
	R	.77	6.70	.66

*Indicates the significance of the coefficient of concordance.

TABLE 2

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY COMPONENT RANKINGS

CASE 2

Initial Velocity 0-Knots	Trajectory Ranking Component	Coefficient of Concordance (0 to 1)	F-Value* (2.92 @ 95% Level) (2.28 @ 90% Level)	Spearman's Rank Correlation Coefficient (-1 to +1)
+20% Variation				
	X	.92	22.52	.88
	Y	.76	6.54	.65
	Z	.76	6.35	.64
	P	.95	38.00	.92
	Q	.95	38.00	.92
	R	.94	31.00	.91
-20% Variation				
	X	.95	38.00	.92
	Y	.72	5.10	.58
	Z	.56	2.55	.34
	P	.87	13.51	.81
	Q	.98	106.57	.97
	R	.82	9.34	.74

*Indicates the significance of the coefficient of concordance.

TABLE 3

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY COMPONENT RANKINGS

CASE 1

Initial Velocity 600-Knots	Trajectory Ranking Conponent	Coefficient of Concordance (0 to 1)	F-Value* (2.92 @ 95% Level) (2.28 @ 90% Level)	Spearman's Rank Correlation Coefficient (-1 to +1)
+20% Variation				
	X	.74	5.69	.61
	Y	.66	3.88	.49
	Z	.73	5.41	.60
	P	.71	4.90	.56
	Q	.96	48.00	.94
	R	.68	4.25	.52
-20% Variation				
	X	.84	10.50	.76
	Y	.78	7.09	.67
	Z	.88	22.00	.82
	P	.61	3.17	.42
	Q	.79	7.62	.69
	R	.66	3.88	.49

*Indicates the significance of the coefficient of concordance.

TABLE 4

CASE 2

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY COMPONENT RANKINGS

Initial Velocity 600-Knots	Trajectory Ranking Component	Coefficient of Concordance (0 to 1)	F-Value* (2.92 @ 95% Level) (2.28 @ 90% Level)	Spearman's Rank Correlation Coefficient (-1 to +1)
+20% Variation				
	X	.85	11.33	.78
	Y	.42	1.44	.13
	Z	.78	7.16	.67
	P	.73	5.38	.59
	Q	.72	5.10	.58
	R	.59	2.84	.38
-20% Variation				
	X	.93	26.15	.89
	Y	.86	12.34	.79
	Z	.65	3.71	.48
	P	.91	18.54	.85
	Q	.96	48.67	.94
	R	.94	31.04	.91

*Indicates the significance of the coefficient of concordance.

TABLE 5

ICARUS

WITHIN CASE
POOLED COMPONENT RANKINGS

CASE 1

Initial Velocity	% Var.	Trajectory Component Rankings Pooled	Coefficient of Concordance	F-Value* (2.21 @ 95% Level) (1.84 @ 90% Level)	Spearman's Rank Correlation Coefficient
0	+20%	X,Y,Z	.67	16.24	.63
	-20%		.73	18.92	.70
	+20%	P,Q,R	.82	36.44	.80
	-20%		.86	49.14	.84
600	+20%	X,Y,Z	.44	6.78	.38
	-20%		.70	18.68	.66
	+20%	P,Q,R	.58	11.05	.53
	-20%		.62	13.05	.57
0+600	+20%	X,Y,Z	.23	5.08	.18
	-20%		.59	24.46	.56
	+20%	P,Q,R	.42	12.31	.38
	-20%		.50	17.00	.47

*Indicates the significance of the coefficient of concordance.

TABLE 6

ICARUS

WITHIN CASE
POOLED COMPONENT RANKINGS

CASE 2

Initial Velocity	% Var.	Trajectory Component Rankings Pooled	Coefficient of Concordance	F-Value* (2.21 @ 95% Level) (1.84 @ 90% Level)	Spearman's Rank Correlation Coefficient
0	+20%	X,Y,Z	.55	9.78	.49
	-20%		.37	4.70	.29
	+20%	P,Q,R	.94	125.33	.93
	-20%		.82	36.44	.80
600	+20%	X,Y,Z	.40	5.33	.32
	-20%		.52	8.67	.46
	+20%	P,Q,R	.65	14.86	.61
	-20%		.93	106.28	.92
0+600	+20%	X,Y,Z	.32	7.88	.28
	-20%		.26	5.85	.21
0+600	+20%	P,Q,R	.72	44.91	.71
	-20%		.84	88.60	.83

*Indicates the significance of the coefficient of concordance.

TABLE 7

BETWEEN CASE
INDIVIDUAL COMPONENT POOLING

Initial Velocity 0-Knots	Trajectory Component Rankings Pooled	Coefficient of Concordance (0 to 1)	F-Value* (2.33 @ 95% Level) (1.93 @ 90% Level)	Spearman's Rank Correlation Coefficient (-1 to +1)
+20% Variation				
	X	.64	9.10	.57
	Y	.69	11.28	.63
	Z	.70	11.42	.63
	P	.90	45.80	.88
	Q	.94	79.40	.93
	R	.76	15.74	.71
-20% Variation				
	X	.82	22.33	.78
	Y	.58	6.77	.49
	Z	.33	2.47	.20
	P	.82	23.35	.79
	Q	.96	119.10	.95
	R	.78	17.33	.73

*Indicates the significance of the coefficient of concordance.

TABLE 8

BETWEEN CASE
INDIVIDUAL COMPONENT POOLING

Initial Velocity 600-Knots	Trajectory Component Rankings Pooled	Coefficient of Concordance (0 to 1)	F-Value* (2.33 @ 95% Level) (1.93 @ 90% Level)	Spearman's Rank Correlation Coefficient (-1 to +1)
+20% Variation				
	X	.47	4.45	.36
	Y	.22	1.42	.06
	Z	.44	3.92	.33
	P	.41	3.48	.29
	Q	.72	12.98	.67
	R	.33	2.49	.20
-20% Variation				
	X	.83	24.00	.79
	Y	.61	7.98	.54
	Z	.56	6.32	.47
	P	.54	5.83	.44
	Q	.71	12.48	.66
	R	.64	8.94	.57

*Indicates the significance of the coefficient of concordance.

TABLE 9

CASE 1

BETWEEN CASE
LINEAR & ANGULAR COMPONENT POOLING

Initial Velocity	% Var.	Component Rankings Pooled	Coefficient of Concordance (0 to 1)	F-Value* (2.10 @ 95% Level) (1.72 @ 90% Level)	Spearman's Rank Correlation Coefficient (-1 to +1)
0-Knots	+20%	X,Y,Z	.54	19.70	.51
	-20%		.41	11.66	.37
	+20%	P,Q,R	.85	98.28	.84
	-20%		.82	79.36	.81
600-Knots	+20%	X,Y,Z	.29	6.93	.25
	-20%		.55	21.15	.53
	+20%	P,Q,R	.42	12.35	.39
	-20%		.61	26.76	.59

*Indicates the significance of the coefficient of concordance.

TABLE R1

CASE 1

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY
COMPONENT RANKINGS OF PARAMETERS
(X,Y & Z)

	0-Knots, +20% Variation			0-Knots, -20% Variation		
Rank	X	Y	Z	X	Y	Z
1.	Roc Thr	Roc Ang	Roc Thr	Cat Thr, Roc Ang	Roc Ang	Roc Ang
2.	Cat Thr	Roc Thr	Roc Ang	S/M C.G.	Cat Thr	Cat Thr
3.	Roc Ang	Roc On	S/M M.I.	Roc Thr	S/M C.G.	Roc Thr
4.	S/M C.G.	Cat Thr	Roc On	S/M M.I.	Roc Thr	Roc On
5.	Roc On, Roc Pos.	Roc Pos	Cat	Roc On	Roc Pos	S/M M.I.
6.	S/M M.I.	S/M C.G.	S/M C.G.	Roc Pos	Roc On	S/M C.G.
7.	Aero	S/M M.I.	Roc Pos	Aero	S/M M.I.	Roc Pos
8.		Aero	Aero		Aero	Aero

	600-Knots, +20% Variation			600-Knots, -20% Variation		
Rank	X	Y	Z	X	Y	Z
1.	S/M C.G.	Aero	Cat Thr	Roc Ang	Cat Thr	Roc Ang
2.	Cat Thr	Cat Thr	S/M C.G.	Cat Thr	Roc Ang	Cat Thr
3.	Roc Ang	Roc Pos	Aero	Aero	S/M C.G.	S/M C.G.
4.	Roc On	Roc On	Roc Thr	Roc Thr, S/M C.G.	Roc On	Aero
5.	Roc Thr	S/M C.G.,S/M M.I.	Roc Ang	Roc Pos	Roc Pos	Roc Thr
6.	Aero	Roc Ang	Roc Pos	S/M M.I.	S/M M.I.	Roc On
7.	Roc Pos	Roc Thr	Roc On	Roc On	Aero	Roc Pos;
8.	S/M M.I.		S/M M.I.		Roc Thr	S/M M.I.

Note: Multiple entries in row/column indicates same rank assigned to parameters by ranking procedure used.

TABLE R2

CASE 1

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY
COMPONENT RANKINGS OF PARAMETERS
(P,Q & R)

Rank	0-Knots, +20% Variation P	Q	R	0-Knots, -20% Variation P	Q	R
1.	Roc Ang	Roc Ang	Roc Ang	S/M C.G., Roc Ang	Roc Ang	Roc Ang
2.	Roc Pos	Roc Pos	Roc Pos	Cat Thr, Roc Pos	S/M C.G.	S/M C.G.
3.	Cat Thr	S/M C.G.	Roc Thr, S/M M.I.	Roc Thr, Roc On, S/M M.I.	Roc Pos	Cat Thr
4.	S/M C.G.	Cat Thr	Cat Thr	Aero	Cat Thr	Roc Pos
5.	Roc Thr	Roc Thr	S/M C.G.		Roc Thr	S/M M.I.
6.	Roc On	Roc On	Roc On		Roc On, S/M M.I.	Roc Thr
7.	S/M M.I.	S/M M.I.	Aero		Aero	Roc On
8.	Aero	Aero				Aero

Rank	600-Knots, +20% Variation P	Q	R	600-Knots, -20% Variation P	Q	R
1.	S/M C.G.	Roc Ang	Cat Thr	Roc Ang	Roc Ang	Roc Ang
2.	Aero	S/M C.G.	Roc Ang	S/M M.I., Roc Pos	Aero	Aero
3.	Roc Pos	Cat Thr	S/M C.G.	Aero	S/M C.G.	Roc Pos
4.	Cat Thr	Aero	Roc On	S/M C.G.	Roc Pos	S/M M.I.
5.	Roc On	Roc Pos	Aero	Cat Thr	Cat Thr	S/M C.G.
6.	Roc Thr, Roc Ang	Roc On	Roc Pos	Roc On	Roc On, S/M M.I.	Cat Thr, Roc Thr
7.	S/M M.I.	S/M M.I.	S/M M.I.	Roc Thr	Roc Thr	Roc On
8.		Roc Thr	Roc Thr			

Note: Multiple entries in row/column indicates same rank assigned to parameters by ranking procedure used.

TABLE R3

CASE 2

WITHIN CASE INDIVIDUAL TRAJECTORY
COMPONENT RANKINGS OF PARAMETERS
(X, Y & Z)

ICARUS

Rank	0-Knots, +20% Variation X	0-Knots, +20% Variation Y	0-Knots, +20% Variation Z	0-Knots, -20% Variation X	0-Knots, -20% Variation Y	0-Knots, -20% Variation Z
1.	Roc Pos	Roc Ang	Roc Ang, Roc Thr	S/M C.G.	Cat Thr	Roc Thr
2.	S/M C.G.	S/M C.G.,Roc Thr	Roc Pos	Cat Trh,Roc Ang	Roc Thr	Roc Pos
3.	Cat Thr	Cat Thr	S/M C.G.	Roc Pos	S/M C.G.	Aero
4.	Roc Ang	Roc On	Roc On	Roc On	Roc On	Cat Thr
5.	Roc On	Roc Pos	S/M M.I.	Roc Thr	Roc Ang,S/M M.I.	Roc On
6.	Roc Thr	S/M M.I.	Cat Thr	S/M M.I.	Aero,Roc Pos	Roc Ang
7.	S/M M.I.	Aero	Aero	Aero		S/M C.G.
8.	Aero					S/M M.I.

Rank	600-Knots, +20% Variation X	600-Knots, +20% Variation Y	600-Knots, +20% Variation Z	600-Knots, -20% Variation X	600-Knots, -20% Variation Y	600-Knots, -20% Variation Z
1.	Cat Thr, Aero	Cat Thr	Roc Ang	Cat Thr	Roc Ang	Roc Ang
2.	Roc Ang	Roc Thr	Roc Thr	Aero	Cat Thr	Roc Thr
3.	Roc Thr	Roc Ang	S/M C.G.	Roc Ang	Roc Thr	S/M C.G., S/M M.I.
4.	Roc On	Roc On, S/M C.G.	Roc Pos	S/M C.G.	Aero	Aero
5.	S/M C.G.,Roc Pos	Aero	Aero	Roc Thr	Roc On	Cat Thr
6.	S/M M.I.	Roc Pos	Cat Thr	Roc On	S/M C.G.	Roc Pos
7.		S/M M.I.	S/M M.I.	Roc Pos	Roc Pos	Roc On
8.			Roc On	S/M M.I.	S/M M.I.	

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R4

CASE 2

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY
COMPONENT RANKINGS OF PARAMETERS
(P, Q & R)

Rank	0-Knots, +20% Variation P	Q	R	0-Knots, -20% Variation P	Q	R
1.	Roc Ang	Roc Ang	Roc Ang	Roc Ang	Roc Ang	S/M C.G.
2.	S/M C.G.	Roc Pos	Roc Pos	Roc Pos	S/M C.G.	Roc Ang
3.	Roc Pos	S/M C.G.	S/M C.G.	S/M C.G.	Roc Pos	Cat Thr
4.	Cat Thr	Cat Thr, S/M M.I.	Cat Thr	Cat Thr, S/M M.I.	Cat Thr	S/M M.I.
5.	Roc Thr	Roc Thr	S/M M.I.	Roc Thr	S/M M.I.	Roc Pos
6.	S/M M.I.	Roc On	Roc Thr	Roc On	Roc Thr	Roc Thr
7.	Roc On	Aero	Roc On	Aero	Roc On	Roc On, Aero
8.	Aero		Aero		Aero	

Rank	600-Knots, +20% Variation P	Q	R	600-Knots, -20% Variation P	Q	R
1.	S/M C.G.	Roc Ang	Roc Pos	S/M C.G.	Roc Ang	Roc Ang
2.	Roc Ang, Roc Pos	S/M C.G.	S/M C.G.	Roc Ang.	S/M C.G.	S/M C.G.
3.	S/M M.I.	Roc Pos	Roc Ang	Roc Pos	Roc Pos	Roc Pos
4.	Roc Thr, Aero	Cat Thr	S/M M.I.	Cat Thr	Cat Thr	Cat Thr
5.	Cat Thr, Roc On	Aero	Cat Thr	S/M M.I.	S/M M.I.	S/M M.I.
6.		Roc Thr	Aero	Roc Thr, Aero	Aero	Aero
7.		Roc On	Roc Thr	Roc On	Roc Thr	Roc Thr
8.			Roc On		Roc On	Roc On

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R5

CASE 1

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY
COMPONENT RANKINGS OF PARAMETERS
(X, Y & Z)

Rank	0-Knots, +20% Variation (X, Y & Z)	0-Knots, -20% Variation (X, Y & Z)
1.	Roc Thr	Roc Ang
2.	Roc Ang	Cat Thr
3.	Cat Thr	Roc Thr
4.	Roc On	S/M C.G.
5.	S/M C.G.	Roc On
6.	S/M M.I., Roc Pos	S/M M.I.
7.	Aero	Roc Pos
8.		Aero

Rank	600-Knots, +20% Variation (X, Y & Z)	600-Knots, -20% Variation (X, Y & Z)
1.	Cat Thr	Roc Ang
2.	S/M C.G.	Cat Thr
3.	Aero	S/M C.G.
4.	Roc Ang, Roc On	Aero
5.	Roc Pos	Roc Thr
6.	Roc Thr	Roc On, Roc Pos
7.	S/M M.I.	S/M M.I.
8.		

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R6

CASE 1

ICARUS

WITHIN CASE INDIVIDUAL TRAJECTORY
COMPONENT RANKINGS OF PARAMETERS
(P, Q & R)

Rank	0-Knots, -20% Variation (P, Q & R)	0-Knots, +20% Variation (P, Q & R)
1.	Roc Ang	Roc Ang
2.	S/M C.G.	Roc Pos
3.	Cat Thr, Roc Pos	Cat Thr
4.	Roc Thr	S/M C.G.
5.	S/M M.I.	Roc Thr
6.	Roc On	S/M M.I.
7.	Aero	Roc On
8.		Aero

Rank	600-Knots, -20% Variation (P, Q & R)	600-Knots, +20% Variation (P, Q & R)
1.	Roc Ang	S/M C.G.
2.	Aero	Cat Thr
3.	Roc Pos	Roc Ang
4.	S/M C.G.	Aero
5.	S/M M.I.	Roc On
6.	Cat Thr	Roc Pos
7.	Roc On	S/M M.I., Roc Thr
8.	Roc Thr	

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R7

CASE 2

ICARUS

WITHIN CASE POOLED TRAJECTORY COMPONENT
RANKINGS OF THE PARAMETERS
(X, Y & Z)

Rank	0-Knots, +20% Variation (X, Y & Z)	0-Knots, -20% Variation (X, Y & Z)
1.	Roc Ang	Roc Pos, Cat Thr
2.	S/M C.G.	Roc Thr
3.	Roc Pos	S/M C.B.
4.	Roc Thr	Roc Ang
5.	Cat Thr	Roc On
6.	Roc On	S/M M.I., Aero
7.	S/M M.I.	
8.	Aero	

Rank	600-Knots, +20% Variation (X, Y & Z)	600-Knots, -20% Variation (X, Y & Z)
1.	Roc Ang	Roc Ang
2.	Roc Thr	Cat Thr
3.	Cat Thr	Roc Thr
4.	Aero	Aero
5.	S/M C.G.	S/M C.G.
6.	Roc On	Roc On
7.	Roc Pos	Roc Pos
8.	S/M M.I.	S/M M.I.

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R8

CASE 2

ICARUS

WITHIN CASE POOLED TRAJECTORY COMPONENT
RANKINGS OF THE PARAMETERS
(P, Q & R)

Rank	0-Knots, +20% Variation (P, Q & R)	0-Knots, -20% Variation (P, Q & R)
1.	Roc Ang	Roc Ang
2.	S/M C.G.	S/M C.G.
3.	Roc Pos	Roc Pos
4.	Cat Thr	Cat Thr
5.	S/M M.I.	S/M M.I.
6.	Roc Thr	Roc Thr
7.	Roc On	Roc On
8.	Aero	Aero

Rank	600-Knots, +20% Variation (P, Q & R)	600-Knots, -20% Variation (P, Q & R)
1.	S/M C.G.	S/M C.G.
2.	Roc Ang, Roc Pos	Roc Ang
3.	S/M M.I.	Roc Pos
4	Aero	Cat Thr
5.	Cat Thr	S/M M.I.
6.	Roc Thr	Aero
7.	Roc On	Roc Thr
8.		Roc On

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R9

BETWEEN CASES POOLED INDIVIDUAL TRAJECTORY
COMPONENT RANKINGS OF THE PARAMETERS
(X, Y & Z)

ICARUS

Rank	0-Knots, +20% Variation X	Y	Z	0-Knots, -20% Variation X	Y	Z
1.	Cat Thr	Roc Ang	Roc Thr	S/M C.G.	Car Thr	Roc Thr
2.	S/M C.G.	Roc Thr	Roc Ang	Cat Thr, Roc Ang	Roc Thr	Roc Ang
3.	Roc Pos	Roc On	Roc On	Roc Thr, Roc Pos	S/M C.G.,Roc Ang,Roc Pos	Cat Thr
4.	Roc Thr, Roc Ang	Cat Thr	S/M M.I.	Roc On	Roc On	Roc Pos
5.	Roc On	S/M C.G.	Roc Pos	S/M M.I.	S/M M.I.	S/M M.I.
6.	S/M M.I.	Roc Pos	S/M C.G.	Aero	Aero	S/M C.G., Roc On
7.	Aero	S/M M.I.	Cat Thr			Aero
8.		Aero	Aero			

Rank	600-Knots, +20% Variation X	Y	Z	600-Knots, -20% Variation X	Y	Z
1.	Cat Thr	Cat Thr	S/M C.G.	Cat Thr	Cat Thr	Roc Ang
2.	S/M C.G., Aero	Aero	Cat Thr, Roc Ang	Roc Ang	Roc Ang	S/M C.G.
3.	Roc Ang	Roc Ang	Roc Thr	Aero	S/M C.G.	Roc Thr
4.	Roc Thr, Roc On	Roc On	Aero	S/M C.G.	Roc Thr	Cat Thr
5.	Roc Pos	S/M C.G.	Roc Pos	Roc Thr	Roc On	Aero
6.	S/M M.I.	Roc Thr, Roc Pos	Roc On	Roc On	Aero	S/M M.I.
7.		S/M M.I.	S/M M.I.	Roc Pos	Roc Pos	Roc On
8.				S/M M.I.	S/M M.I.	Roc Pos

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R10

BETWEEN CASES POOLED INDIVIDUAL TRAJECTORY COMPONENT RANKINGS OF THE PARAMETERS (P, Q & R)

ICARUS

	0-Knots, +20% Variation			0-Knots, -20% Variation		
Rank	P	Q	R	P	Q	R
1.	Roc Ang	Roc Ang	Roc Ang	Roc Ang	Roc Ang	Roc Ang
2.	Roc Pos	Roc Pos	Roc Pos	S/M C.G.	S/M C.G.	S/M C.G.
3.	S/M C.G.	S/M C.G.	S/M C.G.	Roc Pos	Roc Pos	Cat Thr
4.	Cat Thr	Cat Thr	Cat Thr	Cat Thr	Cat Thr	S/M M.I.
5.	Roc Thr	Roc Thr	S/M M.I.	S/M M.I.	S/M M.I.	Roc Pos
6.	S/M M.I.	S/M M.I.	Roc Thr	Roc Thr	Roc Thr	Roc Thr
7.	Roc On	Roc On	Roc On	Roc On	Roc On	Roc On
8.	Aero	Aero	Aero	Aero	Aero	Aero

	600-Knots, +20% Variation			600-Knots, -20% Variation		
Rank	P	Q	R	P	Q	R
1.	S/M C.G.	S/M C.G.	S/M C.G., Roc Ang	Roc Ang	Roc Ang	Roc Ang
2.	Roc Pos	Roc Ang	Cat Thr	S/M C.G.	S/M C.G.	S/M C.G.
3.	Aero	Roc Pos	Roc Pos	Roc Pos	Roc Pos	Roc Pos
4.	Roc Ang	Cat Thr	Aero	S/M M.I.	Aero	Aero
5.	Cat Thr	Aero	Roc On	Cat Thr	Cat Thr	S/M M.I.
6.	Roc On	Roc On, S.M M.I.	S/M M.I.	Aero	S/M M.I.	Cat Thr
7.	S/M M.I.	Roc Thr	Roc Thr	Roc On	Roc On	Roc Thr
8.	Roc Thr			Roc Thr	Roc Thr	Roc On

Note: Multiple entries in a row/column indicate the same rank was assigned to parameters by ranking procedure used.

TABLE R11

BETWEEN CASE POOLED LINEAR TRAJECTORY
COMPONENT RANKINGS OF PARAMETERS
(X, Y & Z)

ICARUS

Rank	0-Knots, +20% Variation (X, Y & Z)	0-Knots, -20% Variation (X, Y & Z)
1.	Roc Ang	Cat Thr
2.	Roc Thr	Roc Ang
3.	Cat Thr	Roc Thr
4.	S/M C.G.	S/M C.G.
5.	Roc Pos	Roc Pos
6.	Roc On	Roc On
7.	S/M M.I.	S/M M.I.
8.	Aero	Aero

Rank	600-Knots, +20% Variation (X, Y & Z)	600-Knots, -20% Variation (X, Y & Z)
1.	Cat Thr	Roc Ang
2.	S/M C.G.	Cat Thr
3.	Aero	Aero
4.	Roc Ang	S/M C.G.
5.	Roc Thr	Roc Thr
6.	Roc On	Roc On
7.	Roc Pos	Roc Pos
8.	S/M M.I.	S/M M.I.

TABLE R12

BETWEEN CASE POOLED ANGULAR TRAJECTORY COMPONENT RANKINGS OF PARAMETERS (P, Q & R)

ICARUS

Rank	0-Knots, +20% Variation (P, Q & R)	0-Knots, -20% Variation (P, Q & R)
1.	Roc Ang	Roc Ang
2.	Roc Pos	S/M C.G.
3.	S/M C.G.	Roc Pos
4.	Cat Thr	Cat Thr
5.	Roc Thr	S/M M.I.
6.	S/M M.I.	Roc Thr
7.	Roc On	Roc On
8.	Aero	Aero

Rank	600-Knots, +20% Variation (P, Q & R)	600-Knots, -20% Variation (P, Q & R)
1.	S/M C.G.	Roc Ang
2.	Roc Ang	S/M C.G.
3.	Roc Pos	Roc Pos
4.	Cat Thr	Aero
5.	Aero	Cat Thr
6.	Roc On	S/M M.I.
7.	S/M M.I.	Roc On
8.	Roc Thr	Roc Thr

APPENDIX D

CODED RANK TABULATIONS OF THE INPUT PARAMETERS

TABLE D1

CODED RANK TABULATION OF THE INPUT PARAMETERS (X,Y & Z)

	S/M C.G.	CATAPULT THRUST	ROCKET THRUST	ROCKET ANGLE	ROCKET ON	ROCKET POSITION	S/M M.I.	AERO
1.	23	1223444	1133	11112233444		3		24
2.	1233	111222234	133444	1234		33		4
3.	1223344	33	1144	1244	1	23	14	223
4.	1244	13	122	3	11222333344	4	1	244
5.	24	14	2234	23	11334	1112234	1233	44
6.	1114	34	3	23	124	12443	122334	23
7.	3		2		224	112244	11344	112333
8.			2		4		222344	11113

TABLE D2

CODED RANK TABULATION OF THE
INPUT PARAMETERS
(P,Q & R)

	S/M C.G.	CATAPULT THRUST	ROCKET THRUST	ROCKET ANGLE	ROCKET ON	ROCKET POSITION	S/M M.I.	AERO
1.	12344	2		1111112222 33333444		4		
2.	112334444	1		2344		111123334	2	222
3.	122333	1123	11	4	12	122334444	114	2
4.	12	111233333 4444	4			12	23334	1224
5.	12	2[illegible]	111333		24	223	133444	4
6.		2	12233344	2	111122233		1223	4444
7.			22444		12333344		1122	11333
8.			22		444		4	111333

APPENDIX E

MATHEMATICAL PRESENTATION OF THE RESIDUAL VALUES

MATHEMATICAL PRESENTATION OF THE RESIDUAL VALUES

The following equations were used to calculate the average value of the residuals at the 95% confidence level.

1. $|RES| = |B| - |VP|$

2. $RES_{i,j,k} = B_{i,j,k} - VP_{i,j,k}$

3. $\sigma^2_{j,k} = \sum_{i=1}^{N_j} (RES_{i,j,k} - \overline{RES}_{j,k})^2 / N_j$

Where:

$|B|$ is a 3-dimensional matrix containing the values of the six seat ejection trajectory components (the 3 linear coordinates x, y and z and the 3 angular rates p, q and r). These trajectory components were obtained by simulating the ejection of the seat/man via ICARUS with the input parameters set at their base case values.

$|VP|$ is a 3-dimensional matrix containing the values of the six seat ejection trajectory components (the 3-linear coordinates x, y and z and the 3-angular rates p, q and r). These trajectory components were obtained by simulating the ejection of the seat/man via ICARUS with one or more of the eight select input parameters varied from their base case values, while the other input parameters were held constant at their base case values.

$|RES|$ is the 3-dimensional matrix of residual values. This matrix was obtained by subtracting each of the 6-trajectory component profiles generated for the varied parameter case from their corresponding base case profiles.

$\overline{RES}_{j,k}$ is the 2-dimensional matrix containing the average values of the residuals over selected intervals of the seat/man ejection trajectory.

$\sigma^2_{j,k}$ is the 2-dimensional matrix containing the variances computed about the average residual values.

Let $i = 1, 2, \ldots, N_j$; where N_j = total number of trajectory elements in the jth interval.

$j = 1$ implies the interval from catapult ignition to catapult separation.

$= 2$ implies the interval from rocket ignition to rocket burnout.

$= 3$ implies the interval from rocket burnout to drogue chute projection.

= 4 implies the interval from drogue chute projection to one second of the trajectory simulation.

k = 1, 2 and 3 implies the 3-linear coordinates (x, y and z) of the seat/man center of gravity respectively expressed in an earth fixed coordinate system in units of feet.

= 4, 5 and 6 implies 3-angular rates (p, q and r) of the seat/man combinates with origin at the seat/man center of gravity, expressed in radians/seconds.

4. $R_{j,k} = \overline{RES}_{j,k} + C_{j,k}\,\sigma_{j,k}$

Where: $0 \leq C_{j,k} \leq 5$

Equation 4 was used to obtain the 2-dimensional matrix of residual values at the 95% confidence level. That is, 95% of the residual values of the kth trajectory component contained in the jth trajectory interval where $\leq$ to this value.

The above $R_{j,k}$ values were then used to rank the eight input parameters selected to be varied in the study.

APPENDIX F

MATHEMATICAL EQUATIONS USED TO COMPUTE THE COEFFICIENTS OF CONCORDANCE AND SPEARMAN'S RANK CORRELATION COEFFICIENTS

MATHEMATICAL EQUATIONS USED TO COMPUTE THE COEFFICIENTS OF CONCORDANCE AND SPEARMAN'S RANK CORRELATION COEFFICIENTS

The following equations were used in the study to determine the Coefficient of Concordance and Spearman's Rank Correlation Coefficient values.

Let: $$S = \sum_{i=1}^{n} (RT_i - EV)^2 \; ; \; EV = \frac{m(n+1)}{2}$$

$$S_{max} = \frac{m^2(n^3 - n)}{12}$$

$$W = S/S_{max}$$

$$F\text{-value} = \frac{(m - 1)W}{1-W}$$

$$\text{Degrees of Freedom for the greater estimate} = (n-1) - \frac{2}{m}$$

$$\text{Degrees of Freedom for the lesser estimate} = (m-1)\left|(n-1) - \frac{2}{m}\right|$$

$$R_{avg} = \frac{m W - 1}{m-1}$$

Where: RT_i = Rank Total, sum of the individual phase ranking values assigned to the i^{th} input parameter.

EV = Expected value of the parameters

S_{max} = Maximum possible sum of squares

m = number of phases or intervals used to rank the parameters

n = number of items to be ranked (8)

W = Coefficient of Concordance

F-value = F-value associated with the Coefficient of Concordance

R_{avg} = the average value of Spearman's Rank Correlation Coefficient.

i = 1, 2, ..., 8 (Number of parameters to be ranked).

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